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PRELIMINARY LAUNCH VEHICLE FLIGHT EVALUATION REPORT NASA APPLICATIONS TECHNOLOGICAL SATELLITE (ATS) PROGRAM FLIGHT NO. 1, NASA ATLAS-AGENA NO. 19 (LAUNCHED DECEMBER 6, 1966)

by the Staff of the Lewis Research Center
Lewis Research Center
Cleveland, Ohio

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION · WASHINGTON, D.C. · 1967

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SUMMARY

The NASA Applications Technological Satellite - 1 (ATS-1) Atlas/Agena Vehicle, carrying 1550 lb of separable payload, was successfully launched from Complex 12, Air Force Eastern Test Range (AFETR) December 6, 1966, at 2112:00.876 EST. The vehicle flight consisted essentially of four phases: an Atlas boost, an Agena first burn, an intervening Agena/spacecraft coast, and an Agena second burn. The flight resulted in a spacecraft orbit well within the required accuracy. The vehicle was launched on the first attempt within one second of the launch window opening. No unscheduled holds occurred during countdown. All Aerospace Ground Equipment (AGE) operated satisfactorily during countdown and launch, except that the 2-inch motion switch malfunctioned at lift-off. Lift-off time (2-in. motion) was derived from the time of the 8-inch motion switch signal.

All Atlas systems performed satisfactorily. All Agena systems performed satisfactorily with the exception of a momentary drop in engine chamber pressure during second burn. This momentary drop had no adverse effect on the flight results. The Agena was the seventh Standard Agena, out of approximately 140 flown, to experience a momentary decay in chamber pressure. The exact cause of this anomaly is unknown at this time. An USAF/NASA supported engineering and test program has been initiated to determine the cause.

The ATS-1 flight was the first to use as a spacecraft aerodynamic shroud the Standard Agena Clamshell (SAC) shroud. The shroud performed successfully during the flight.

This report describes the ATS-1 launch vehicle flight performance in detail. Each major Atlas and Agena vehicle borne system, the ground radio guidance system, and the spacecraft shroud system are described. The performance of each system is evaluated, and significant data are presented.

INTRODUCTION

The ATS-1 launch vehicle was the first of three Atlas/Agena vehicles for the ATS Program. It was also the 12th Atlas/Agena vehicle launched under the direction of the Lewis Research Center and the 88th Atlas/Agena launched for all NASA and Air Force programs.

The objective for the ATS-1 vehicle was to place the 1550 lb. spacecraft in the proper transfer ellipse to approximately synchronous altitude. An apogee motor aboard the spacecraft would be used to attain approximately synchronous velocity and to remove inclination. In order to meet this objective the Atlas was used to boost the combined Agena/shroud/spacecraft into a suborbital coast ellipse. The Agena then performed two separate burns to place the spacecraft into the proper transfer orbit.

VEHICLE DESCRIPTION

The ATS-1 launch vehicle consisted of a Standard Atlas (SLV-3), a Standard Agena D (SS-01B) second stage, and a Standard Agena Clamshell (SAC) shroud. Both stages and the SAC shroud were modified to satisfy ATS-1 mission requirements. Figures 1 through 5 illustrate the general arrangement of the ATS Atlas, Agena, SAC shroud and spacecraft. The composite vehicle, including the shroud/spacecraft assembly, was 109.3 feet long and weighed 279 000 lb at lift off. Reference 1 contains a detailed description of the launch vehicle systems.

Atlas

The Atlas is propelled by an engine system which burns liquid oxygen (LOX) and high grade kerosene (RP-1) propellants. The Atlas B-1 and B-2 equipment pods (fig. 2) contain the basic electrical and instrumentation equipment and associated wiring used for all missions, and allow for the installation of program peculiar equipment. For ATS, a program peculiarized electrical distribution box, telemetry, autopilot and guidance subsystem equipment were installed in the equipment pods.

There are nine system categories of equipment that make up the Atlas: the structure, propulsion, hydraulic, propellant utilization, pneumatic, guidance and flight control, electrical, telemetry, and flight termination systems.

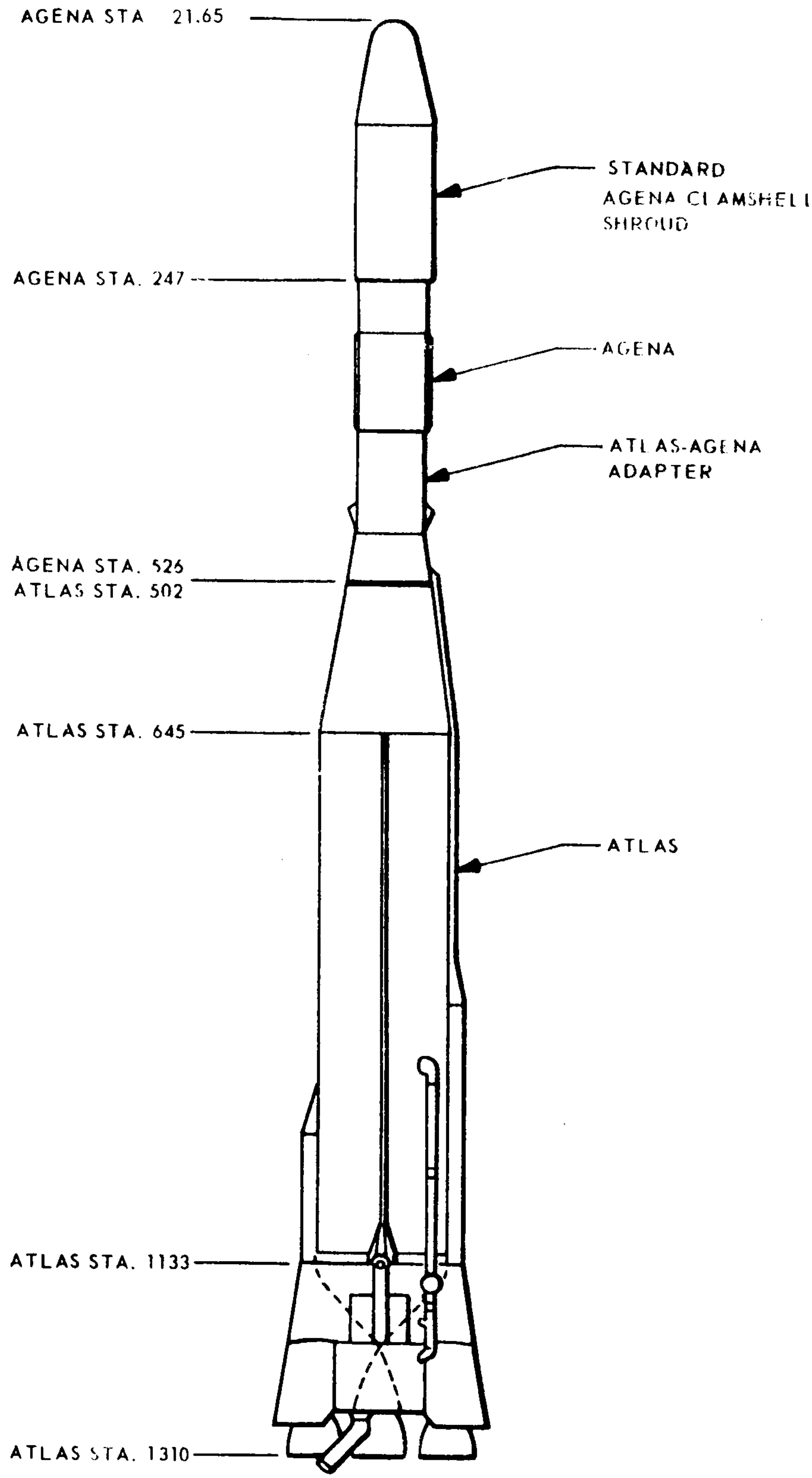
Agena

The Agena is a standardized vehicle that can be configured to perform as an upper stage of the launch vehicle and to perform on-orbit functions if desired. The Agena is propelled by a 16 000 lb thrust engine system which burns unsymmetrical dimethylhydrazine (UDMH) fuel and inhibited red fuming nitric acid (IRFNA) as an oxidizer.

There are five system categories of equipment that make up the Agena. These are the structure, propulsion, electrical, guidance and control, and communications and control systems. The Agena design readily allows for the adaptation of these systems to meet mission requirements.

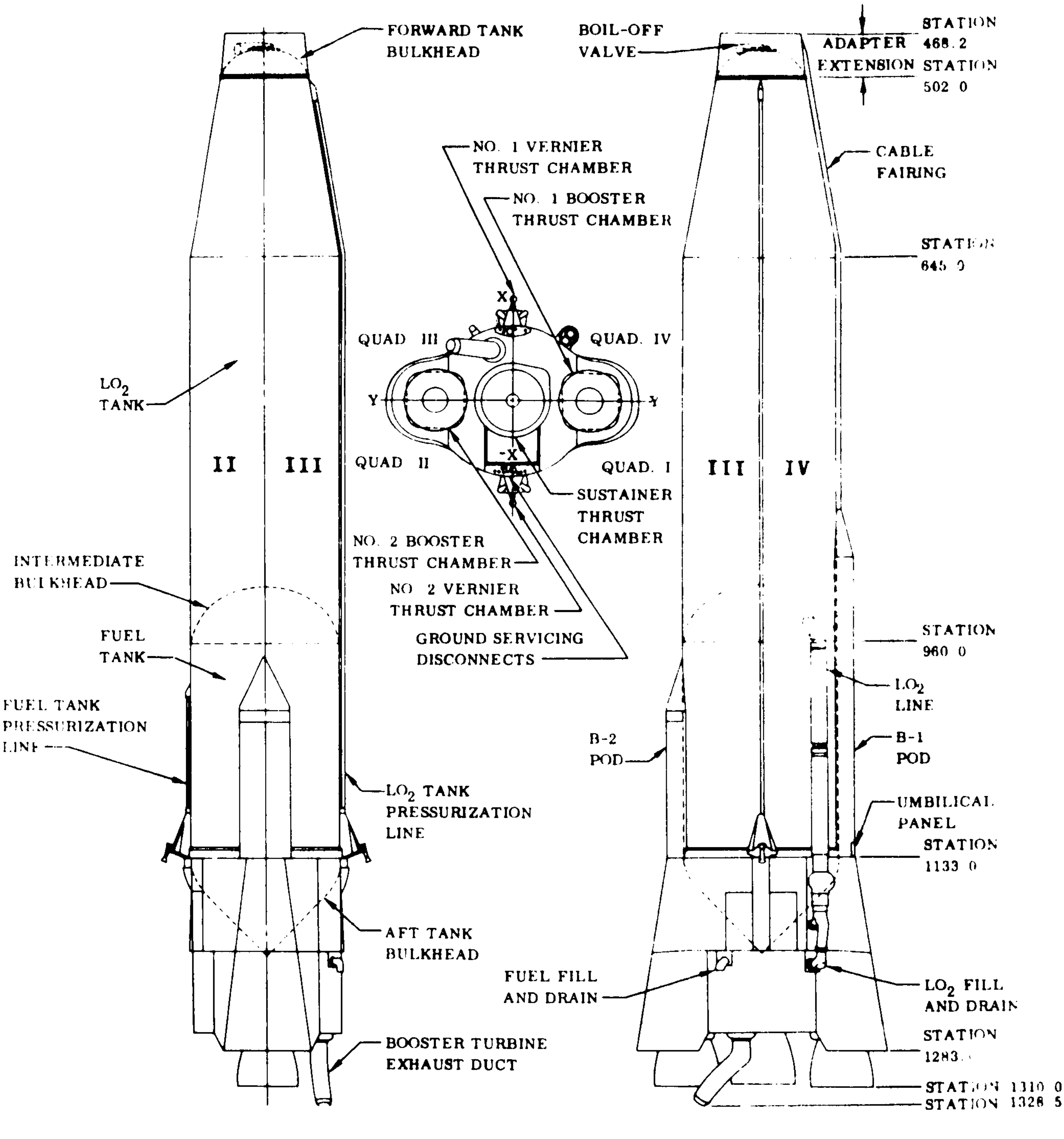
Shroud System

The SAC shroud protects the spacecraft during ascent through the atmosphere. The SAC shroud is 18.75 ft long and can accommodate a spacecraft volume up to 256 cu. ft.



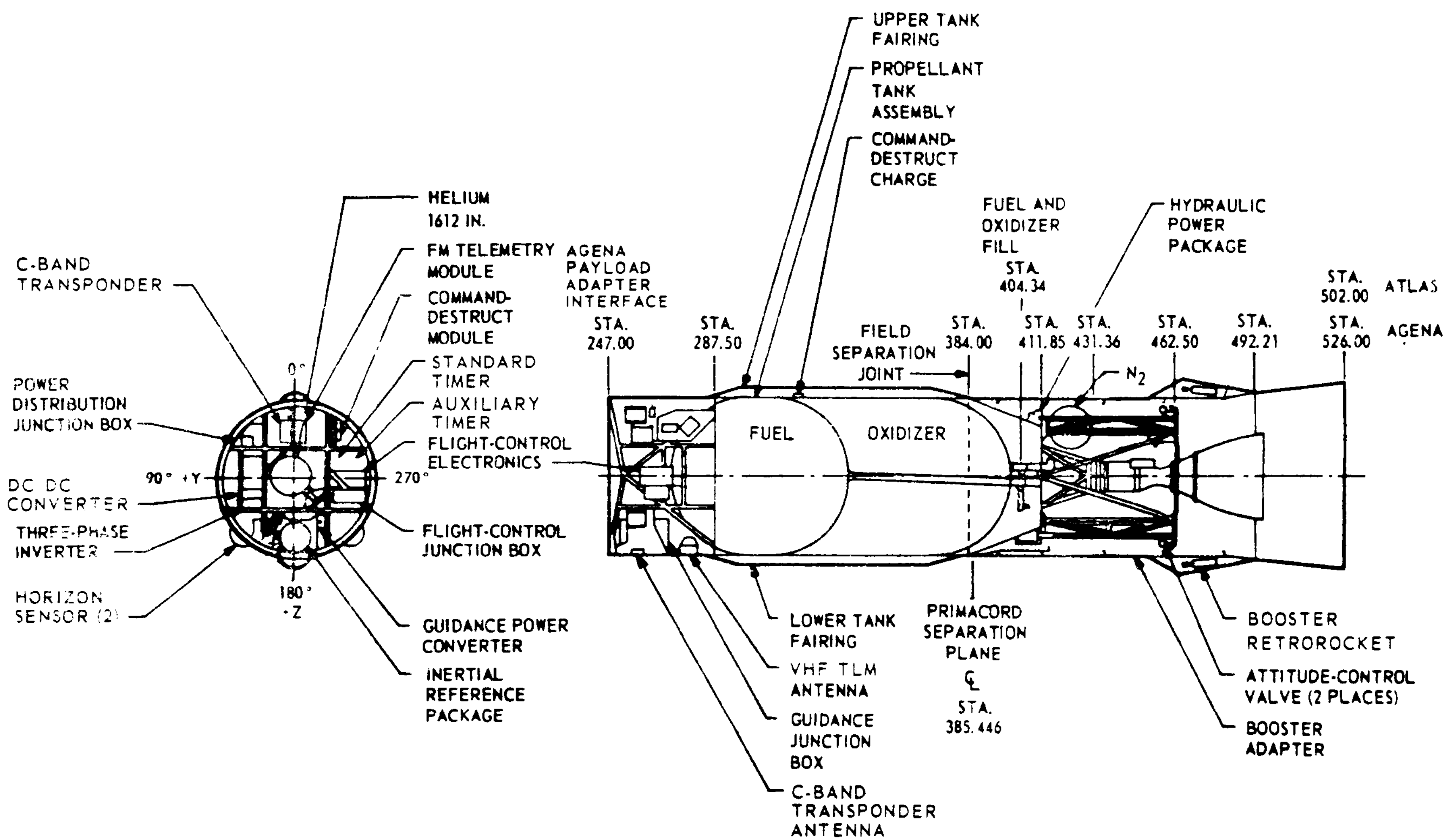
ATS SPACE VEHICLE PROFILE

FIGURE 1



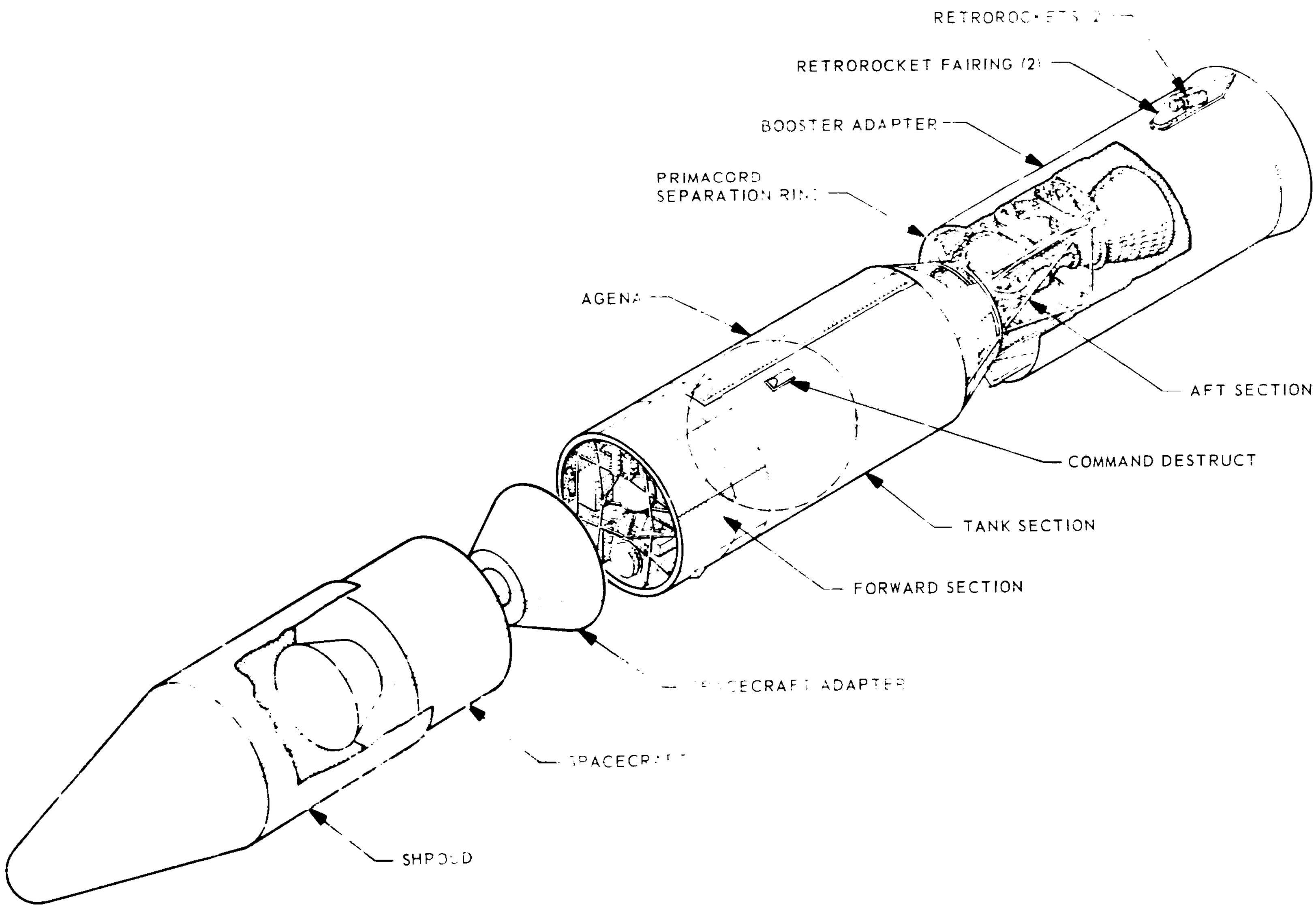
ATLAS SLV-3 CONFIGURATION

FIGURE 2



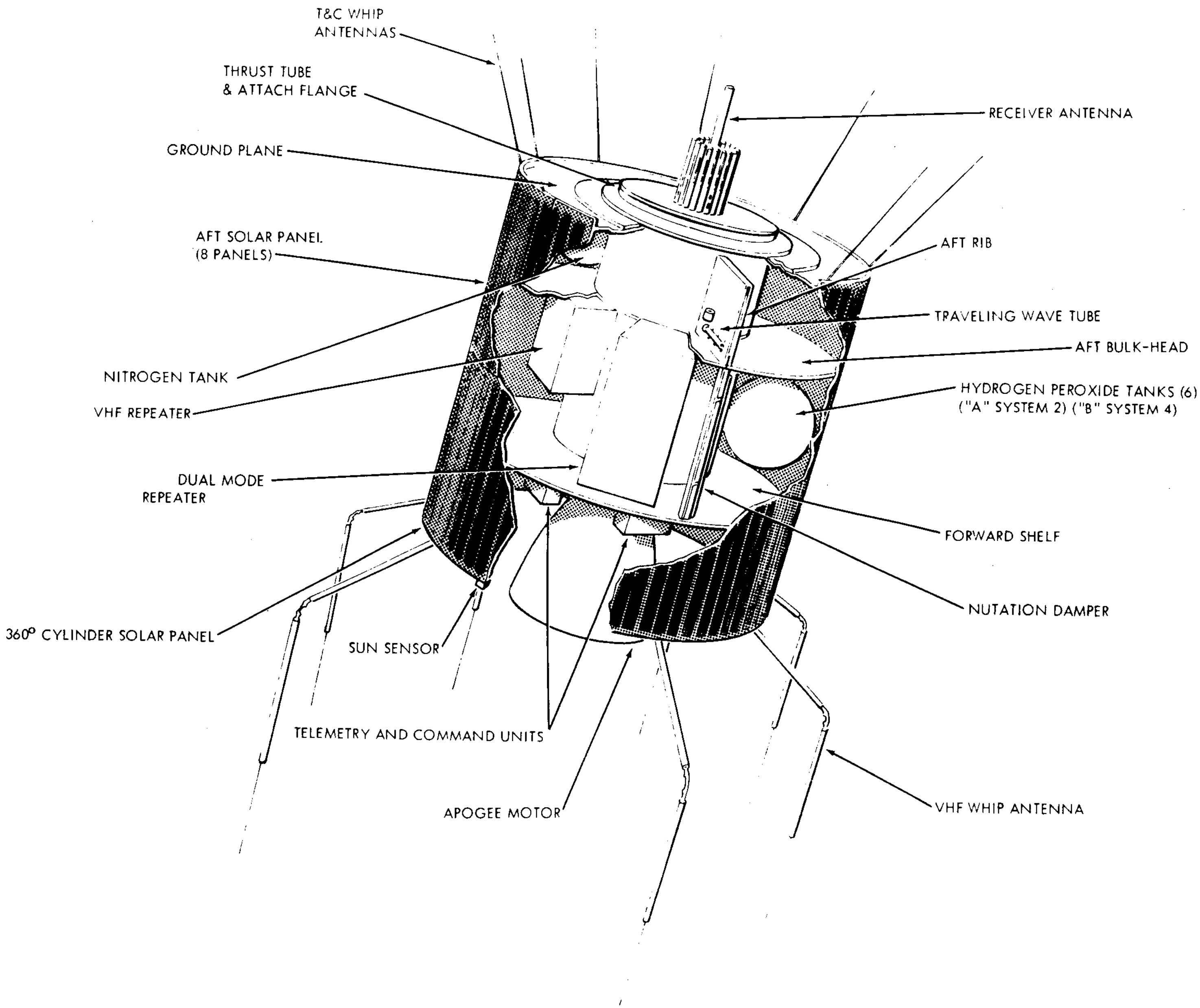
AGENA INBOARD PROFILE

FIGURE 3



ATS-1 AGENA/SHROUD/SPACECRAFT

FIGURE 4



ATS-1 SPACECRAFT

FIGURE 5

TRAJECTORY

Summary

ATS-1 was launched from Complex 12 AFETR December 6, 1966, at 2112:00.876 EST. The flight azimuth was fixed at 103.9 deg. A comparison of nominal and actual times for major flight events is given in table I. A detailed sequence of flight events for the ATS-1 mission is provided as Appendix A to this report.

Atlas. - The trajectory performance of the Atlas through separation was satisfactory with all requirements being fulfilled at Agena insertion into the coast ellipse. The Atlas boost trajectory was slightly lofted because of a 1.4 deg. deficiency in the pitchover angle as measured at 100 sec. of flight (T+100). The maximum vertical dispersion was about 15 000 ft., decreasing to about 12 000 ft. at Atlas vernier engine cutoff. The Atlas trajectory was also slightly left of the nominal trajectory, mainly because of a 0.22 deg. roll dispersion at lift off.

Agena. - Agena performance during first and second burn was close to nominal. Deviations between nominal[1] and actual spacecraft orbit parameters after spacecraft injection were within the allowable three sigma dispersions.

Trajectory Plan

The Atlas provides the ascent propulsive power to place the Agena/spacecraft in a prescribed suborbital coast ellipse. The Atlas flight consists of three powered phases: a booster engine phase, a sustainer engine phase, and a vernier engine phase. Following Atlas/Agena separation, the Agena engine is ignited and burns until it places the Agena/spacecraft into a 100 n.mi. parking orbit. The Agena/spacecraft coasts in the parking orbit until the Agena engine is reignited. The Agena second burn phase injects the Agena/spacecraft into a transfer ellipse to approximately synchronous altitude. The Agena/spacecraft is injected into the transfer orbit at the first descending node of the parking orbit. Prior to spacecraft separation, the Agena pitches up 9.36 deg. and yaws left 57 deg. to place the spacecraft motor thrust axis in the attitude required during spacecraft motor burn. Three seconds after spacecraft separation, the Agena performs a yaw right of 237 deg. to orient the Agena tail first in the direction of the inertial velocity vector. This is done so that any Agena tail-off will further reduce its orbit and preclude impact with the spacecraft.

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[1]The word "nominal", as used in this report denoted a design, programmed, or expected value. Three sigma (σ) dispersions about nominal define acceptable limits for flight or hardware performance.

TABLE I

ATS SIGNIFICANT FLIGHT EVENTS

Nominal Time[1] (sec)	Actual Time (sec)	Event Description
0	0	Liftoff-2112:00.876 EST
129	129.1	Atlas Booster Cutoff
132	131.8	Booster Engine Jettison
293.1	293.0	Atlas Sustainer Cutoff
295.8	288.2	Start Agena Timer
312.8	312.9	Atlas Vernier Cutoff
315.0	315.1	Atlas/Agena Separation
366.8	359.2	Fire First Burn Ignition Squibs
368.0	360.4	Agena Steady State Thrust (90% Chamber Pressure)
376.8	369.3	Fire Nose Shroud Squibs
528.1	521.7	Agena Engine Cutoff (Velocity Meter)
1177.8	1170.3	Fire Second Burn Ignition Squibs
1179.0	1171.4	Agena Steady State Thrust (90% Chamber Pressure)
1258.0	1248.7	Agena Engine Cutoff (Velocity Meter)
1334.8	1327.3	Start 9.36 Pitchup Maneuver
1354.8	1347.3	Stop 9.36 Pitchup Maneuver
1364.8	1357.2	Start 57° Yaw Left Maneuver
1383.8	1376.4	Stop 57° Yaw Left Maneuver
1394.8	1387.3	Fire Spacecraft Separation Squibs
1397.8	1390.3	Start 237° Yaw Right Maneuver
1476.8	1469.3	Stop 237° Yaw Right Maneuver

(1) Obtained from Reference 2.

Trajectory Results

Winds aloft. - Winds aloft at the time of launch were predominately from the West, attaining a maximum speed of 110 fps at an altitude of 49 450 ft as shown in figure 6. These winds were light and had only a minor effect on the vehicle flight path. Changes in wind velocity, however, produced strong wind shears at altitudes from 37 000 ft to 46 000 ft.

Atlas booster phase. - A comparison of the nominal and actual trajectories in the vertical plane during the booster phase is shown in figure 7.(1) Trajectory lofting occurred primarily because of small autopilot dispersions during execution of the booster pitch program. A total pitchover deficiency of 1.4 deg was encountered at T+100 sec. Approximately 1.0 deg of the 1.4 deg can be attributed directly to autopilot dispersions. At booster engine cutoff (BECO), the actual trajectory was 3650 ft higher in altitude and 4250 ft less in ground range than nominal.

A projection of the nominal and actual trajectories in the horizontal plane is shown in figure 8. The actual trajectory is seen to be left of the nominal trajectory throughout the booster phase of the flight. As determined from reconstruction, this deviation resulted primarily from cross-range winds and a slightly greater roll than the programmed roll. The actual flight azimuth resulting from the roll maneuver was 103.68 deg, or 0.22 deg left of the programmed azimuth. Thrust misalinement and yaw gyro drift were indicated from telemetry to be small and, therefore, had little if any effect on the trajectory.

Figure 9 shows the nominal and actual velocity histories measured with respect to a rotating earth. The difference between the actual and nominal velocities during the booster phase did not exceed 10 fps. Radio guidance was enabled at T+80 sec. Booster pitch steering was initiated at T+103.0 sec with a pitch down command to correct for the lofted trajectory. (Radio guidance yaw steering is not used during the booster phase.) Transmission of the radio guidance discrete for booster engine cutoff occurred at T+128.84 sec. Thrust decay began at T+129.1 sec. at a vehicle longitudinal acceleration level of 6.07 g's. Tracking data indicates that at BECO, the actual velocity was about 10 fps greater than nominal. These deviations in velocity were the result of tail winds and slightly better than nominal engine performance. The booster engines were jettisoned at T+131.8 seconds.

Atlas sustainer phase. - The actual and nominal trajectories from booster engine jettison to sustainer engine cutoff (SECO) are illustrated in figures 7 and 8 for the pitch and yaw planes. The actual trajectory profile is seen to be lofted with respect to the nominal trajectory during the sustainer phase. The altitude at SECO was 14 000 ft higher than the nominal altitude. The cross-range deviation at SECO was approximately 12 750 ft left of the nominal trajectory.

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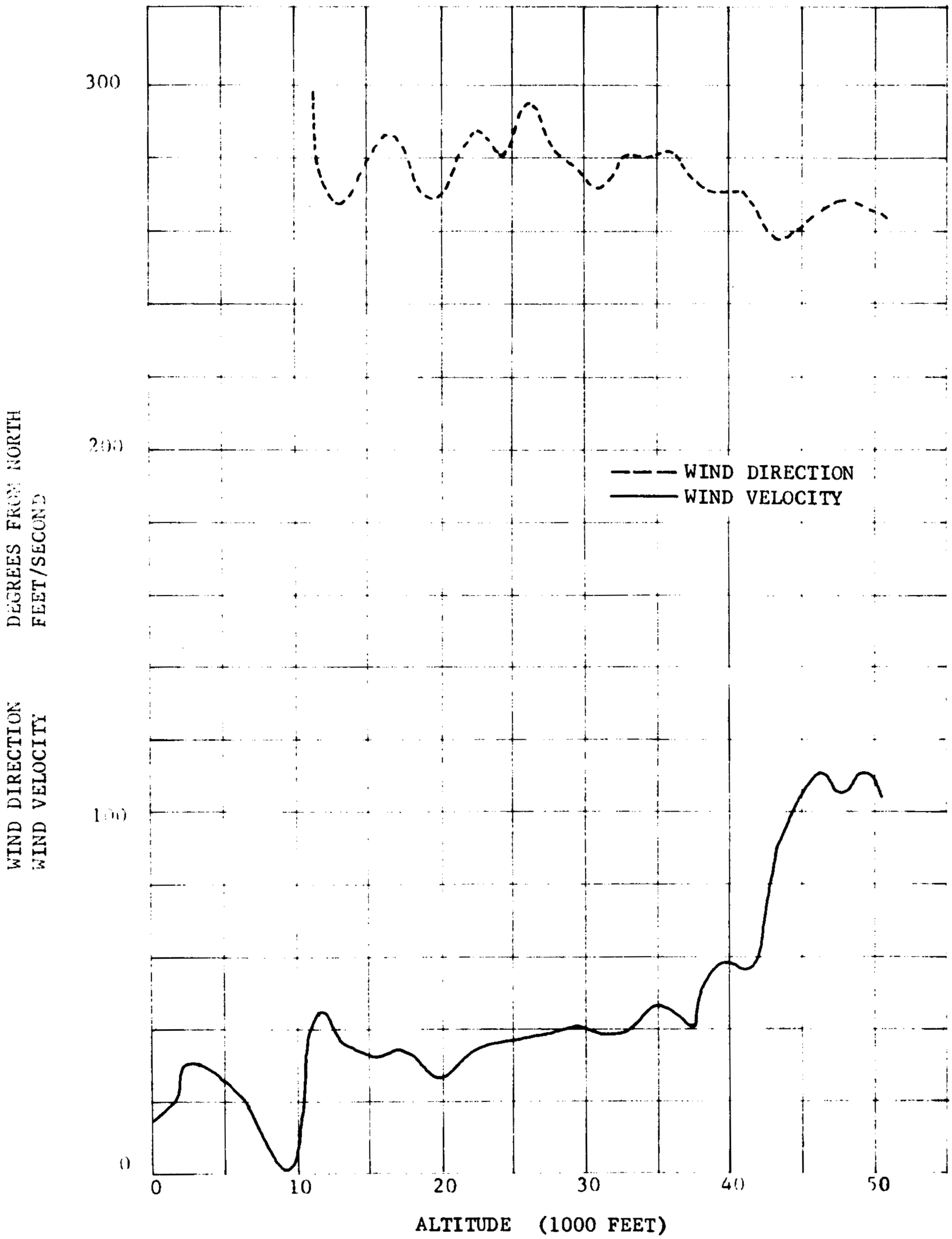
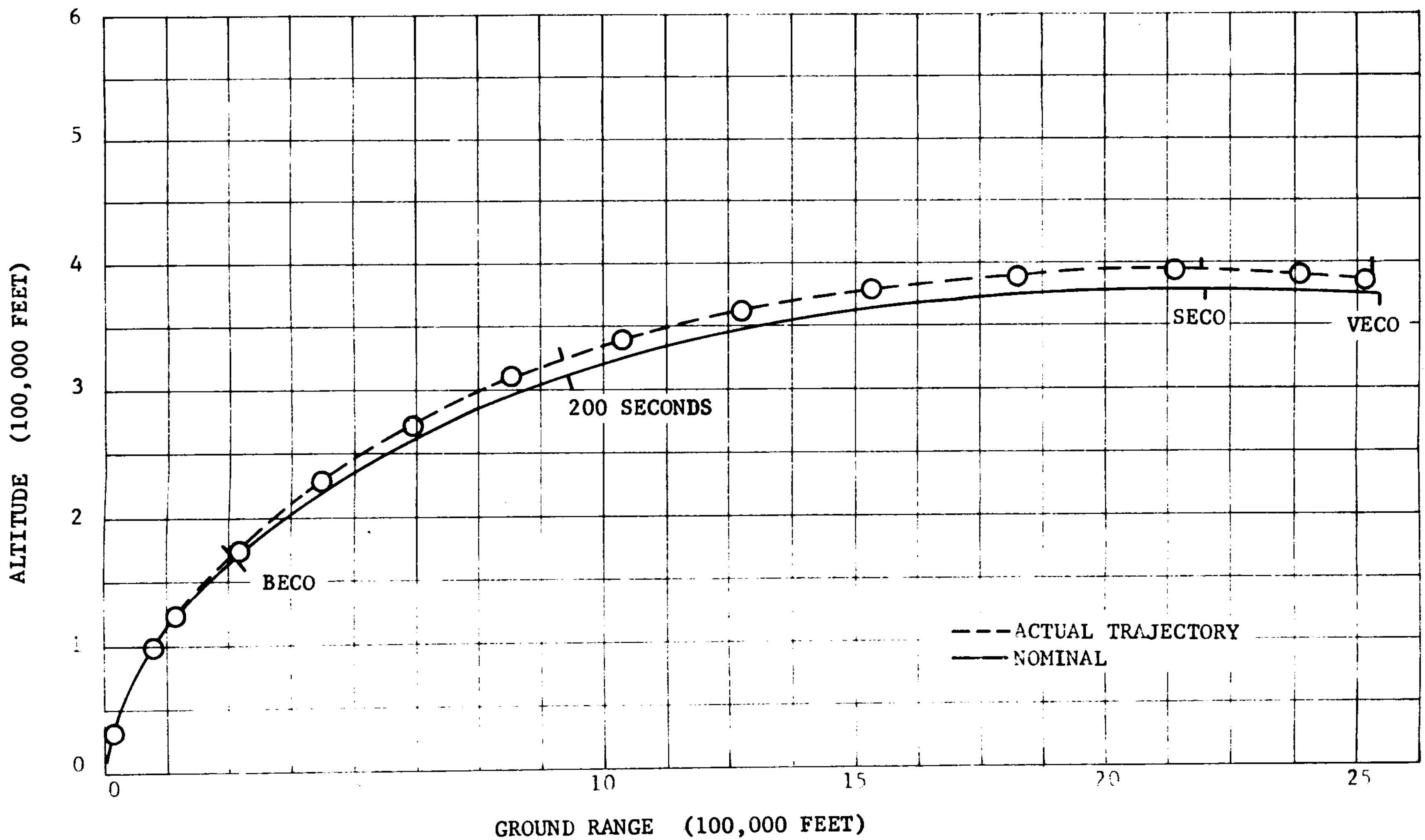
(1) The trajectory data presented herein for the Atlas flight phase were computed from the Air Force Eastern Test Range tracking data by the Radio Corporation of America for the Air Force Eastern Test Range and are presented in reference 3.



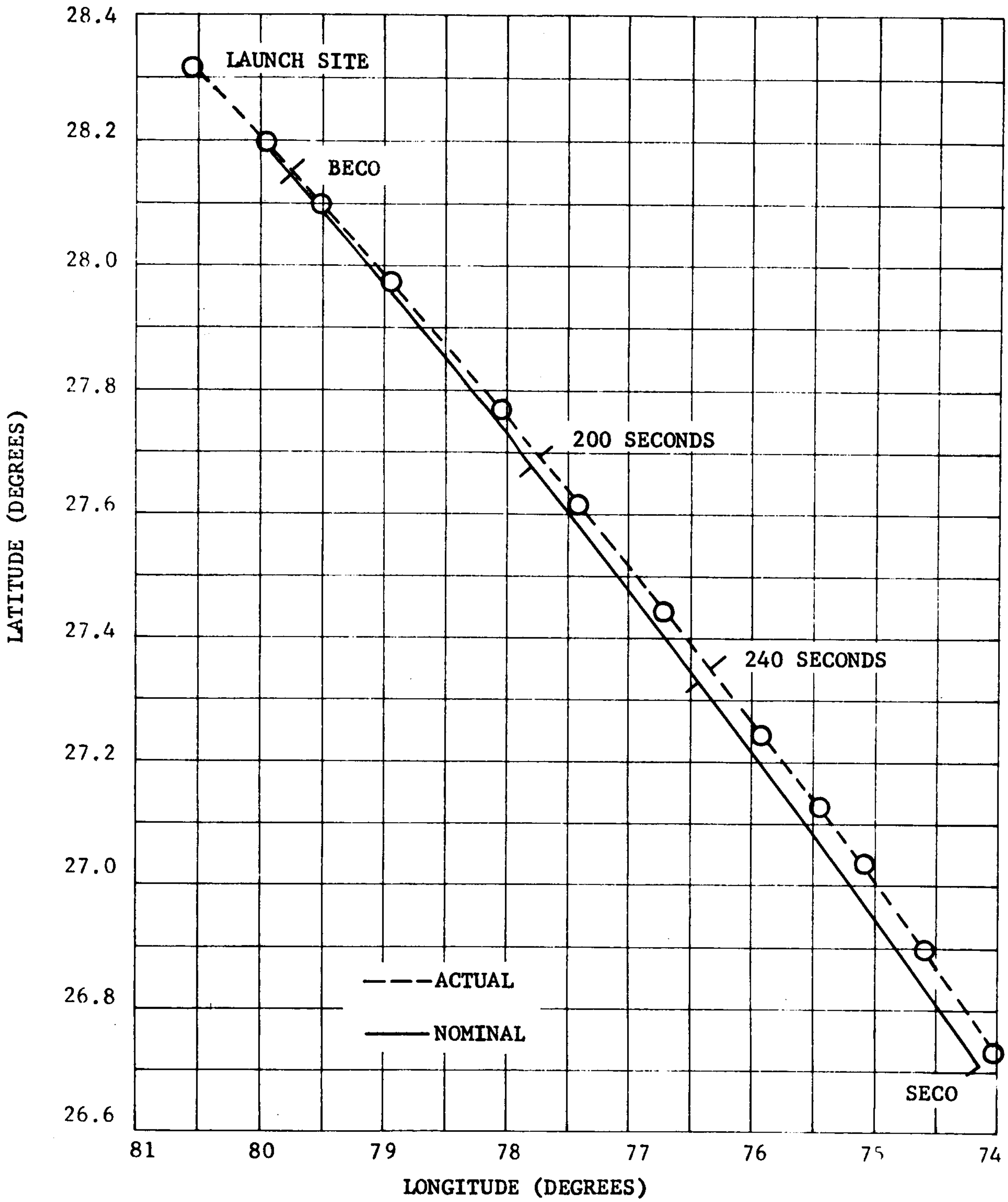
WINDS ALOFT AT T-0 BALLOON RELEASE

FIGURE 6



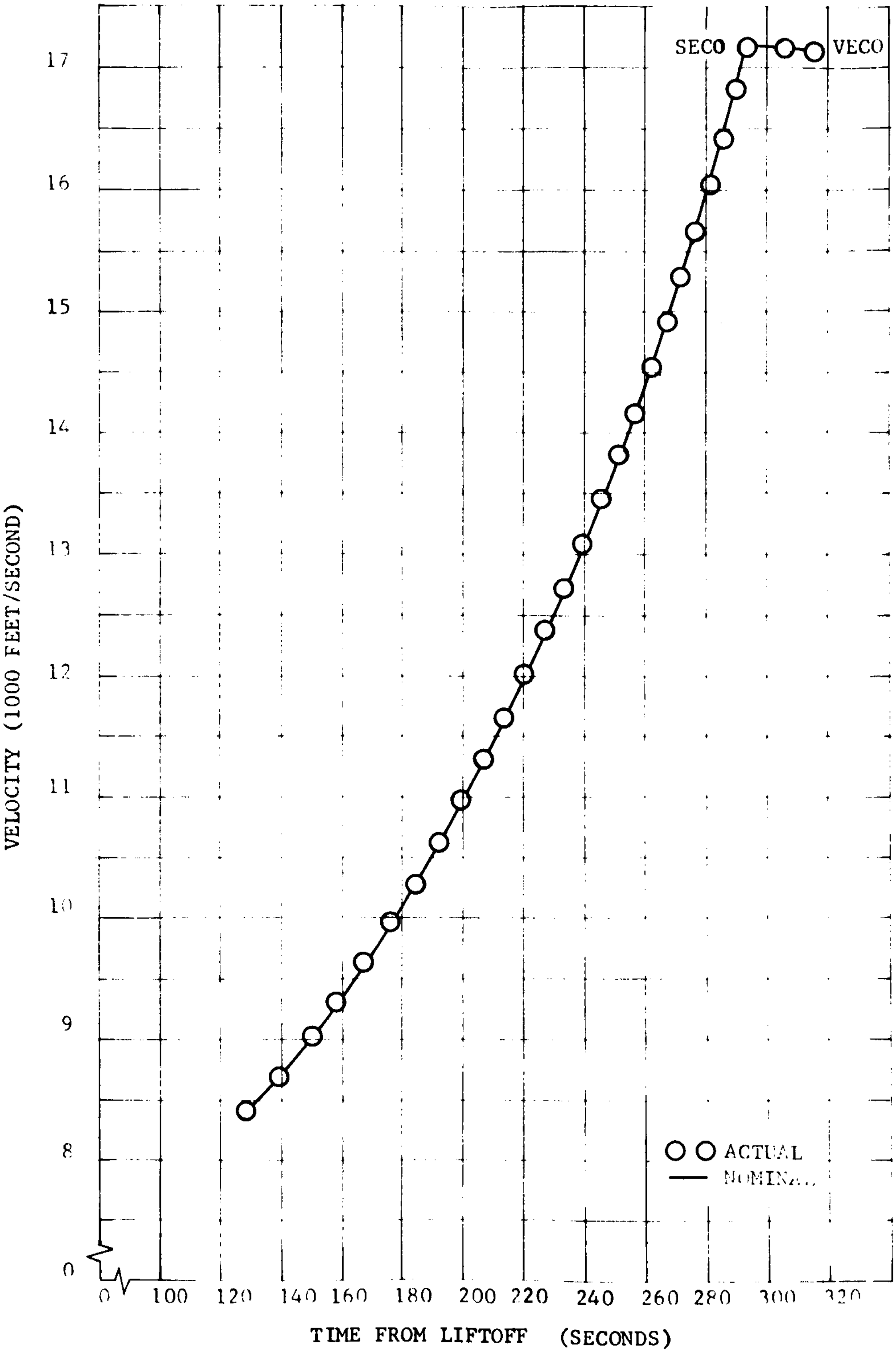
ALTITUDE AND GROUND RANGE DISPLACEMENT

FIGURE 7



TRAJECTORY PROJECTION IN THE HORIZONTAL PLANE

FIGURE 8



VELOCITY MEASURED WITH RESPECT TO A ROTATING EARTH

FIGURE 9

The actual and nominal sustainer phase velocity histories, relative to a rotating earth, are shown in figure 9. Due to increased gravitational losses associated with a steeper than nominal ascent following booster staging, the velocity at SECO was about 30 fps less than nominal. (This decrement is compatible with the lofted spatial position of the vehicle. The velocity and position at SECO provided an energy that gave a very close to nominal boost ellipse.)

The radio guidance Start Agena Timer (SAT) discrete started the Agena timer at T+288.2 sec, or 7.6 sec before the nominal time for this event. The ground guidance system sensed that the Agena would be injected on the ellipse at an altitude higher than the nominal and, therefore, the Agena would reach apogee earlier than predicted. The guidance adjusted the SAT time by the 7.6 sec so that Agena first burn would occur at the proper altitude. Sustainer engine operation was terminated at T+293.0 sec as a result of a radio guidance command.

Atlas Vernier phase. - Vernier engine burn duration after SECO was 19.9 sec, or 0.2 sec longer than the nominal time. Vernier phase pitch-up and yaw left steering commands were issued by radio guidance in order to place the vehicle in the proper attitude before separation of the Atlas from the Agena. These commands displaced the vehicle 0.96 deg up in pitch and 1.26 deg left in yaw. A comparison of the actual coast ellipse parameters (derived at Vernier engine cutoff (VECO) plus two sec) with the nominal values is shown in table II.[2]

Agena first burn phase. - Atlas/Agena separation occurred by radio guidance command at T+315.1 sec, which was 0.1 sec later than the nominal time. Due to radio guidance transmission of the SAT discrete 7.6 sec earlier than the nominal time, the actual times for all Agena timer events listed in table I are earlier by this amount.

After Atlas/Agena separation, the Agena pitchdown maneuver placed the vehicle in the proper attitude for initiating first burn. Agena first burn ignition and shroud separation occurred at T+359.2 sec and T+369.3 sec, respectively. First burn duration (90% chamber pressure to velocity meter cutoff) was 161.3 sec, which is slightly longer than the nominal burn time. At the end of Agena first burn, the Agena/spacrcraft was in a parking orbit. The agena timer was set so that the Agena/spacecraft would coast to the proper position for Agena second burn. The actual parking orbit parameters are listed in table III.

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(2) The Atlas Coast Ellipse and Agena orbit data presented herein were computed from Air Force Eastern Test Range Tracking data by the Lockheed Missiles & Space Company for Lewis Research Center and are presented in reference 2.

TABLE II. - ASCENT COAST ELLIPSE

Parameter	Nominal	Actual
Semi-major Axis (kilofeet)	14 502.4	14 502.1
Semi-minor Axis (kilofeet)	12 691.3	12 690.8
Velocity Magnitude (fps)	18 488.8	18 488.2
Vertical Velocity (fps)	1 439.5	1 437.6
Lateral Velocity (fps)	0	-4.5

TABLE III. - AGENA PARKING ORBIT

Parameter	Actual
Apogee (n.mi.)	105.
Perigee (n. mi.)	100.
Period (min.)	88.2
Inclination (deg.)	31.082

Agena second burn phase. - Agena second burn ignition occurred at T+1170.3 sec. The second burn duration (90% chamber pressure to velocity meter cutoff) of 77.3 sec was slightly less than the nominal burn time. During second burn, a momentary decrease in chamber pressure occurred. The pressure returned to a value slightly greater than the initial value. The average effect of the chamber pressure variation was to increase engine thrust thereby shortening the burn duration. Actual transfer orbit parameters are listed in table IV.

Post second burn phase. - After second burn shutdown, the Agena performed the programmed pitchup maneuver (nominal 9.36 deg), followed by the programmed yaw left maneuver (nominal 57 deg). At T+1387.3 sec, the Agena and spacecraft separated. Three seconds later, the Agena performed the programmed yaw right maneuver (nominal 237 deg).

ATLAS VEHICLE PERFORMANCE

Structure System

Summary. - The structure system's performance was satisfactory. No structural anomalies were encountered.

Description. - The airframe structure consists of two sections: the tank section and the booster section.

The tank section consists of a thin wall, all-welded, monococque stainless steel cylinder, which is divided into a fuel compartment and a (LOX) compartment by an intermediate bulkhead. The tank section is 10 feet in diameter, with an ellipsoidal bulkhead enclosing the conical forward end, and a thrust cone enclosing the aft end. A propellant anti-slosh system of annular baffles is installed in the liquid oxygen compartment. Tank structure rigidity is derived from internal pressurization. Fairings are provided on the tank to form equipment pods to protect the equipment against aerodynamic effects.

The booster section (aft section) consists of a thrust structure, booster engines, nacelles, and a fairing installation. The booster section is attached to the thrust ring at the aft end of the tank section by a mechanism that releases this section by way of jettison tracks at booster engine jettison.

Performance. - The structure system's performance was satisfactory and all measured loads were within their expected limits. The peak longitudinal load factor during flight was 6.1 g at booster engine cutoff. Based on T-0 wind sounding data, the maximum booster engine gimbal angles required to react out flight bending loads on the structure were calculated to be 1.97 deg pitch and 0.99 deg yaw. The actual maximum booster engine gimbal angles were 1.67 deg pitch and 0.54 deg yaw.

TABLE IV. - FINAL AGENA-SPACECRAFT TRANSFER ORBIT

Parameter	Actual
Apogee (n.mi)	19 851
Perigee (n.mi)	97
Inclination (deg)	31.30
Eccentricity	0.7361
Period (min)	646.59
Semi-major Axis (n.mi.)	13 418

Propulsion System

Summary. - The propulsion system's performance was satisfactory.

Description. - The propulsion system consists of the booster, sustainer, and vernier engine assemblies. The booster assembly has two combustion chamber/thrust nozzle combinations that provide 165 000 lb of thrust each. Both combustion chambers are fed by turbo-pump systems which are driven by a common gas generator. The sustainer assembly has a sustainer engine that provides 57 000 lb of thrust, and two vernier engines that provide 575 lb of thrust each.[3] All engines are single-start, constant-thrust, rocket engines which burn liquid oxygen and a high grade kerosene (RP-1) as propellants.

Performance. - The propulsion system's performance was satisfactory. No unusual engine operating conditions, trends, or characteristics were noted. Engine start and thrust buildup transients were within acceptable limits. All shutdown transients were within acceptable limits. Propulsion system parameters are tabulated in table V.

Hydraulic System

Summary. - The hydraulic system's performance was satisfactory.

Description. - The hydraulic system consists of two independent systems, the booster system and the sustainer/vernier system. The booster system's variable displacement pump and accumulator furnish the hydraulic pressure required for booster engine gimballing. The sustainer/vernier system's variable displacement pump, and three accumulators furnish the hydraulic pressure required for sustainer and vernier engine gimballing and for operating the propellant utilization valve, the head-suppression valve, and the gas generator blade valve. During vernier solo operation, after SECO, the vernier engines are provided with hydraulic pressure from two pressurized accumulators.

Two significant modifications to the hydraulic system were flown for the first time on the ATS-1 Atlas. The booster and sustainer accumulators were replaced by accumulators having smaller volume, lower precharge pressure, and a significantly different tubing arrangement. Improved hydraulic servo actuators were installed to correct servo valve nulling problems and actuator leakage problems. These modifications were incorporated to improve the performance and reliability of the system.

Performance. - The hydraulic system's performance was satisfactory. Pressure stability was maintained in both the booster and sustainer circuits except for the usual transients which occur at engine start and booster engine cutoff. The values of steady-state hydraulic pressures monitored during flight are given in table VI.

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(3) All thrusts are rated at sea level.

TABLE V. - PROPULSION SYSTEM PERFORMANCE

Performance Parameters	Sea Level Design	2-inch Motion	BECO	SECO	VECO
B-1 Chamber Pressure (psia)	578	576	576	---	---
B-2 Chamber Pressure (psia)	578	580	584	---	---
Booster Gas Generator Chamber Pressure (psia)	531	528	528	---	---
B-1 Pump Speed (rpm)	6 340	6 306	6 306	---	---
B-2 Pump Speed (rpm)	6 279	6 250	6 280	---	---
Sustainer Chamber Pressure (psia)	706	710	700	700	---
Sustainer Gas Generator Discharge Pressure (psia)	631	640	648	656	---
Sustainer Pump Speed (rpm)	10 196	10 049	10 034	9 980	---
V-1 Chamber Pressure:					
(Pump Feed) (psia)	257	256	264	264	---
(Tank Feed) (psia)	216	---	---	---	220
V-2 Chamber Pressure:					
(Pump Feed) (psia)	257	256	260	264	---
(Tank Feed) (psia)	216	---	---	---	220

TABLE VI. - HYDRAULIC SYSTEM FLIGHT DATA

Measurement	After Oil Evacuation psia	Peak Pressure Prior to Liftoff, psia	Liftoff psia	BECO Time 129.1 sec psia	SECO Time 293.0 sec psia	VECO Time 312.9 sec psia	Nominal Liftoff to SECO
Sustainer/Vernier Pressure	1890	3250	3080	3080	3080	1365	2950/3150
Sustainer Pump Discharge		3290	3080	3080	3080		2950/3150
Booster Pump Discharge		3500	3150	3045			2950/3150
B_1 Engine Accumulator	1855	3500	3115	3080			2950/3150
Sustainer Return Line	42	48	48	48	48		
Booster System Return Line	84	96	90				

Propellant Utilization System

Summary. - The propellant utilization system's performance was satisfactory

Description. - The propellant utilization system regulates the oxidizer and fuel flow to the sustainer engine. This maintains a desired ratio between the oxidizer and fuel remaining in the tanks to minimize propellant residual imbalance at sustainer engine cutoff.

The propellant utilization system in the ATS-1 Atlas is a digital system, sampling propellant ratio at six discrete points during flight, and adjusting the oxidizer/fuel mixture ratio as necessary. The system is capable of adjusting the mixture ratio ± 15 percent about the nominal of 2.28

Performance. - Propellant utilization system's performance was satisfactory. The last fuel and LOX head sensing ports uncovered 5 sec and 6 sec prior to SECO, respectively. Burnable propellant residuals at SECO were calculated to be 306 lb of fuel and 499 lb of LOX. These residuals would have allowed 2.7 sec longer engine burn time. The fuel residual at theoretical LOX depletion was calculated to be 71 lb.

Pneumatic System

Summary. - The pneumatic system's performance was satisfactory.

Description. - The vehicle borne pneumatic pressurization system performs two principal functions: it supplies internal tank pressure for structure rigidity, and it provides the head pressure required for correct propellant pump operation. In addition, the system provides pressurized gas to the engine control subsystem, and to the booster section release fittings (to effect separation). Helium (He) for tank pressurization is supplied from six refrigerated spheres located in the booster engine section and attached to the thrust barrel. The spheres are externally refrigerated by liquid nitrogen during the loading operation prior to lift off. This system also pressurizes the hydraulic reservoirs and the lube oil tanks. This storage system is jettisoned with the booster engine at BECO. The engine control helium bottle is located on the sustainer section, and provides helium for both booster and sustainer engine controls. The separation helium bottle, jettisoned with the booster section, provides helium pressure to actuate the booster section release fittings.

Performance. - The pneumatic system's performance was satisfactory. All tank pressures were satisfactory and all control functions were performed properly. Pneumatic system parameters during flight are shown in table VII. LOX tank ullage pressure oscillations were within the range experienced for previous flights. Oscillations have always been encountered on Atlas boosters that use this type of LOX regulator. Prior to liftoff, oscillation frequencies of 3.25 Hz were measured. The oscillation amplitudes (differential pressure across the bulkhead) varied with a maximum peak-to-peak amplitude of 3.0 psid. After liftoff, these oscillations increased in frequency to 5.25 Hz and increased in amplitude slightly. These oscillations damped out within the time span experienced for previous flights.

Guidance and Flight Control

Summary. - The autopilot and radio guidance performance were satisfactory. The Agena sequence timer was started properly by a command from the ground guidance system. The Agena/spacecraft was successfully separated from the Atlas after VECO and placed into a coast ellipse with the correct energy.

Description. - Atlas guidance is provided by two interrelated systems: the autopilot system and the Mod III Radio Guidance System. The autopilot directs the vehicle in a preplanned open loop mode from liftoff through Atlas/Agena separation. The Mod III Radio Guidance System generates and transmits pitch and yaw steering commands to the vehicle in order to provide the attitude corrections required as a result of vehicle deviations from the preplanned trajectory. Transmission of steering commands during the booster phase is limited to the period from T+100 sec to T+110 sec, and then only if the deviations from the preplanned trajectory are greater than one sigma. Subsequent to booster engine jettison, steering commands are issued as required during the sustainer and vernier phases of flight.

The Mod III Radio Guidance System is also the primary mode for initiating discrete commands for BECO, SECO, VECO, SAT, and Atlas/Agena separation.

The major elelents of the autopilot system are the flight programmer, gyro reference packages, servo-control electronics, and hydraulic controllers. Timing and switching functions are performed by the flight programmer using command inputs from radio guidance for certain events.

Steering commands from either the flight programmer or radio guidance are sent to the gyro package, which monitors the instantaneous difference between actual and desired vehicle attitude. In each of the three axes (pitch, roll, and yaw) single degree of freedom, rate integrating displacement gyros form a prime reference, and steering commands are effected by torquing these gyros. Signals proportional to the difference between actual and desired vehicle attitude, as measured by the gyro gimbal angle, are sent to the respective gyro signal amplifiers for input to the servo control units. Rate damping is provided by signals generated by three rate gyros, which sense vehicle angular rates in pitch, yaw, and roll and introduce corrective signals into the gyro signal amplifiers.

TABLE VII. - PNEUMATIC SYSTEM PERFORMANCE

Parameter	Units	Design Range	Relief Valve Crack	Flight Values			
				T-0	BECO	SECO	VECO
Oxidizer Tank Ullage Pressure	psig	31.0/28.5	33.0-34.0	29.8	29.7	29.0	29.0
Fuel Tank Ullage Pressure	psig	67.0/64.0	69.5-70.5	64.8	64.9	49.9	49.9
Intermediate Bulkhead Delta P	psid			11.0			
Integrated Start System Regulator Discharge Pressure	psig	635/565		655	590	590	590
Sustainer Controls Bottle Pressure	psig	3400/2900		3052	2770	2480	1400
Booster Helium Bottles Pressure	psia	3400/2900		3066	630	--	---
Booster Helium Bottles Temperature	^{o}F	-306 Max		-319	-382	--	---
Booster Controls Regulator Discharge Pressure	psig	785/715		780	780	--	---

The Mod III Radio Guidance System includes the vehicle borne pulse beacon, rate beacon, and decoder; and a ground station comprised of a monopulse X-band track subsystem, a continuous wave L-band rate subsystem, and a digital guidance computer subsystem.

The track subsystem, which measures range, azimuth and elevation, transmits a composite message-train containing an address code and the coded steering and discrete commands. The vehicle borne pulse beacon, if the address code of the received signal is correct, transmits a return pulse to the ground station, and acts as a receiver which operates in conjunction with the decoder for the radio-guidance command link. The airborne decoder receives the pulse-position coded message from the pulse beacon, decodes the message, and provides the pitch and yaw steering commands and discrete command outputs to the autopilot system.

The rate subsystem transmits two continuous wave signals of different frequencies from a single ground antenna. The vehicle borne rate beacon is interrogated by the signals from the ground subsystem, and transmits a continuous wave signal at a frequency equal to the arithmetic average of the frequencies of the received signals. The return signal is received by the central rate station and two outlying rate leg receiving stations. The two-way doppler shift and phase relation of the signals, as received at the three separate ground antennas, are used to determine the vehicle range, azimuth, and elevation rates.

Acquisition of the vehicle is accomplished through use of an acquisition cube procedure, or an optical tracking acquisition aid, or slaving to range, azimuth, and elevation data supplied by the AFETR. In the acquisition cube procedure which is the primary method of acquisition, the antennas are slewed to one of seven predetermined positions along the programmed trajectory. These positions represent cubes defined by range, azimuth and elevation. The first cube on the programmed trajectory is selected at a point where good lock can be obtained as the vehicle passes through the cube.

A conical scan antenna on the same mount as the main track subsystem antenna is used for initial acquisition. Once the vehicle is acquired by the conical scan antenna, tracking is automatically switched to the main track antenna. The rate subsystem antennas are slaved to the track subsystem antenna; however, during initial acquisition, rate subsystem lock is normally accomplished before track subsystem lock due to differences in antenna gains and beamwidths and to receiver sensitivities.

The position and velocity information from the track and rate subsystems is fed to the data processing circuitry in the ground computer where the commands are generated. The steering commands are fed to the autopilot through the vehicle borne decoder and thereby control the gimballing of the engine thrust chambers to guide the vehicle onto the desired flight path. The BECO discrete terminates booster-engine thrust at a specified value of longitudinal acceleration. The SECO and VECO discretes are transmitted when the vehicle energy (position and velocity) is such that the desired coast ellipse will be achieved. The SAT discrete is timed so that the initiation of Agena first burn will occur at a fixed time prior to the coast ellipse apogee.

Performance. - The autopilot performance was satisfactory. Liftoff transients were within acceptable limits. Following liftoff, the initial roll transient was in the clockwise (CW) direction (viewing the vehicle from aft) with a maximum displacement of 0.5 deg at a peak rate of 2.8 deg/sec. Autopilot activation of engine gimballing (by 42 in. motion switch) quickly damped this transient. The resulting roll overshoot transient (following engine gimbal activation) was 0.5 deg counter clockwise (CCW) at a peak rate of 0.4 deg/sec. This transient was also quickly damped. During the programmed roll maneuver, the roll rate gyro indicated an average roll rate of 0.115 deg/sec for 13 sec. This resulted in a total roll of 1.5 deg CCW. The programmed launch azimuth required a total roll of 1.28 deg. The pitch program was initiated as planned. The actual against nominal times and amplitudes of each step are listed in table VIII. The actual roll and pitch maneuver dispersions were within acceptable limits.

Maximum dynamic pressure occurred during the period from T+60 sec to T+85 sec. Disturbances were small and were damped out in the normal time span.

The autopilot's null commands for the booster engines in pitch and yaw at BECO resulted in a pitchup displacement of less than 0.1 deg, and a yaw left of less than 0.6 deg. Immediately following booster staging, the sustainer engine returned the vehicle to the attitude it had before BECO. The staging transients recorded on the autopilot's gyros were small. After sustainer burn and vernier solo, Atlas/Agena separation was initiated by radio guidance. The vehicle was in a stable attitude at the time of separation.

Post flight evaluation of ground and vehicle data indicates that both the ground station and the vehicle borne quidance equipment performed satisfactorily.[4]

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(4) Much of the data presented in this section was obtained from reference 4.

TABLE VIII. - PITCH PROGRAM

Time Interval		Step Level	
Programmed sec	Actual sec	Programmed degrees/sec	Actual degrees/sec
0 - 15	0 - 15	0.000	0.000
15 - 35	15 - 35	1.018	1.000
35 - 45	35 - 45	0.848	0.850
45 - 58	45 - 58	0.509	0.500
58 - 70	58 - 70	0.678	0.650
70 - 82	70 - 82	0.806	0.800
82 - 91	82 - 91	0.678	0.650
91 - 105	91 - 105	0.551	0.550
105 - 120	105 - 120	0.387	0.400
120 - stg	120 - stg	0.254	0.275

The track subsystem conical scan antenna acquired the vehicle in the first cube at T+60.5 sec. The automatic switch to monopulse tracking with the main antenna occurred at T+63.4 sec, and good data were presented to the compter by T+66.5 sec.

Track lock was continuous from acquisition until T+400.6 sec, 85.5 sec after Atlas/Agena separation. Track lock was then intermittent until final loss of lock occurred at T+411.0 sec when the Atlas was at an elevation angle of 2.82 deg above the horizon. The signal received by the track subsystem throughout the flight was within 3 db of the theoretically expected level.

Lock at all rate antennas was accomplished by T+59.3 sec, and good data were presented to the computer by T+63.0 sec. Rate lock was continuous thereafter until T+392.9 sec, followed by intermittent lock and then by final loss of lock coincident with track loss when the Atlas was 2.82 deg above the horizon. The signals received by the central rate antenna were within 4 db of the expected (calculated) levels, and the signals received at the two rate leg antennas were within 2 db of those received at the central rate antenna.

The computer subsystem's performance was satisfactory throughout the countdown and vehicle flight. Following the flight, the guidance program was successfully verified before removal of the protram from the computer. A simulated retun of the flight indicated that no transient errors occurred during the flight.

The automatic gain control (AGC) monitor indicated a received signal strength of -54 dbm at acquisition, with a signal increase to approximately -28 dbm at T+64 sec. The received signal strength reached a maximum of -8 dbm at T+79 sec, and gradually decayed to -33 dbm at Agena separation; it then continued to decay until T+400 sec, when the received signal strength was less than -70 dbm.

The magnetron current monitor indicated intermittent beacon response during acquisition until T+59 sec. Except for a normal momentary telemetry dropout during booster staging, the magnetron current monitor indicated good beacon response with no missing pulses from T+59 sec to T+402 sec, and intermittent beacon response until the magnetron current dropped to zero at T+411 sec.

The rate beacon AGC monitors, #1 and #2, indicated that the received signal strength of the two carrier frequencies, reached a level in excess of -75 dbm by T+57 sec, and so remained until approximately T+383 sec. Both signal strengths gradually decayed to the threshold sensitivity of the receiver, -85 dbm, at approximately T+393 sec. The rate beacon phase detector and power output monitors indicated that the received signals were processed and that the return signal was properly transmitted back to the ground station during the period from T+57 sec to T+393 sec.

The steering and discrete commands transmitted from the ground station were properly processed by the decoder.

Spurious pitch and yaw commands were evident, as experienced on prior flights, during the periods of intermittent pulse beacon lock between T+50.6 and T+59.0 sec during cube acquisition. The spurious commands were less than plus or minus 20 percent of maximum command during the above interval, and were inhibited by the vehicle borne autopilot.

Guidance steering was enabled within the vehicle borne autopilot at T+80 sec. Booster steering was initiated from the ground guidance station at T+103.0 sec, with an initial pitchdown command of 20 percent of maximum for a duration of one computer cycle (0.5 sec), followed four seconds later by another pitchdown command of 20 percent for one computer cycle. These commands resulted in a vehicle pitchdown rate of 0.25 deg/sec. No yaw steering commands were transmitted during booster steering. It may be concluded that booster steering by radio guidance was minimal.

Sustainer steering was initiated at T+137.6 sec. The largest steering commands were a yaw right command of 60 percent of maximum steering and a pitchdown command of 75 percent, followed by a pitchup command of 100 percent. Both pitch and yaw steering commands were reduced to within ± 10 percent of maximum steering by T+143.8 sec, and so remained until vernier attitude steering. The amplitude and duration of steering commands indicated normal steering by radio guidance.

Vernier attitude steering resulted in a 100 percent pitch up and a 90 percent yaw left command, both for a duration of one second. These were within the acceptable limits. These commands caused the vehicle to pitch up 0.96 deg and to yaw left 1.26 deg. Table IX gives the times at which the actual BECO, SAT, SECO, VECO and Atlas/Agena separation discretes were generated at the guidance computer.

Electrical System

Summary. - The electrical system's performance was satisfactory.

Description. - The electrical system is comprised of four 28 Vdc manually activated batteries; a 28 Vdc to 115 Vac, 3 phase, 400 Hz inverter; a power changeover switch; a distribution box; two junction boxes; and related harnesses. The main battery provides 28 Vdc to the autopilot system, the radio guidance system, the propellant utilization system, and the propulsion system. The main battery also powers the inverter, which supplies 115 Vac to the autopilot and Phase A reference to the radio guidance system. The other three batteries power the telemetry system (one battery) and the flight termination system (two batteries).

TABLE IX - RADIO GUIDANCE CONTROLLED EVENTS

Flight Event and Trajectory Function	Actual Discrete Generation Time	Vehicle Location at Time of Discrete	Vehicle Velocity at Time of Discrete	Discrete Duration
BECO (seconds)	T+128.837			0.497
Range (feet)		319,241		
Azimuth (degrees)		100.257		
Elevation (degrees)		32.576		
Range Rate (feet/second)			8,089	
SAT (seconds)	T+288.197			0.637
SECO (seconds)	T+292.914			0.920
Range (feet)		2,233,581		
Azimuth (degrees)		103.580		
Elevation (degrees)		10.256		
Range Rate (feet/second)			16,876	
VECO (seconds)	T+312.740			0.594
Range (feet)		2,567,899		
Azimuth (degrees)		103.707		
Elevation (degrees)		8.787		
Range Rate (feet/second)			16,858	
Shroud Separation(1) (seconds)	T+313.937			0.497
SEP (seconds)	T+315.427			to end

(1) This discrete is normally used for over-the-nose shroud separations; however, since ATS-1 used the SAC shroud, this discrete was not used by the vehicle even though it was sent by the ground station.

Performance. - The electrical system's performance was satisfactory. Voltage and current levels were adequately furnished to the dependent components of the systems to meet all requirements, and were within specifications. Steady-state electrical parameter outputs are shown in table X.

Telemetry System

Summary. - The telemetry system's performance was satisfactory.

Description. - The telemetry package consists of an 18 channel PAM/FM/FM transmitter, commutator assemblies, signal condition components, and the subcarrier oscillators. The telemetry transmitter operates on an assigned frequency of 249.9 mHz at an output power level of 3.5 to 6 watts. The transmitter utilizes the standard IRIG subcarrier channels 1 through 18. Continuous channels 1, 2, 3, 4 and 12 are continuous direct (no subcarrier oscillator); channels 5 through 10 are continuous; channel 11 is commutated at 2.5 rps; channel 13 is commutated at 5 rps; channels 14 and 17 are not used for this program; channels 15 and 16 are commutated at 10 rps; and channel 18 is commutated at 30 rps. The complete list of transducers flown on the Atlas is given in Appendix B.

Performance. - The performance of the telemetry and instrumentation system was satisfactory. No measurement failures were noted, although telemetry (TLM) station 4 (MILA) data playback was slightly noisy. A data dropout on Channels 15, 16 and 18 occurred at T+249 sec. This was noted at all Cape stations, and was due to the antenna look angle at that time. No dropout at T+249 sec was reported at downrange stations. The commutator for channels 15, 16 and 18 was slow in attaining steady-state speed after the second guidance command test, but no commutator problems were experienced during flight. A summary of TLM data is listed in table XI. Appendix C specifies the stations used to record the Atlas TLM.

Flight Termination System

Summary. - The flight termination system maintained capability to destroy the Atlas but was not needed.

Description. - The flight termination system consists of a single destructor unit with redundant batteries; signal receiving, decoding and switching equipment. Flight termination is effected, when necessary, on command from the ground, which provides an engine cutoff signal and fires the destructor which ruptures the propellant tanks.

Performance. - Performance of the flight termination system was satisfactory. Prelaunch checks were completed without incident. TLM AGC measurements indicated that the capability to terminate flight was

TABLE X. - ELECTRICAL SYSTEM PERFORMANCE

	Countdown Redline Values	Liftoff	BECO	SECO	Atlas/Agena Separation
1. Vehicle dc Bus, Vdc	26.6 min.	28.0	27.9	28.1	28.1
2. Inverter Frequency, Hz	394.0 min. 404.0 max.	399.7	400.0	400.6	400.6
3. Phase A Voltage, Vac	113.6 min. 117.0 max.	116.2	115.5	115.3	115.2

TABLE XI. - TELEMETRY DATA

Parameter	T-0	BECO	SECO	VECO	Shroud Sep.	Atlas/Agena Sep.
RF Signal Strength Microvolts	10 000	80*	18	29	30	30

COMMUTATION RATES

Channel	Planned RPS	Actual rps	Comments
15	10.0	9.16 rps min. 9.3 rps max.	Channels 15, 16 and 18 driven by a common motor Spec. limits for Channel 15 are 8.5 to 10.5 rps
16	10.0	Same as Channel 15	Spec. limits for Channel 16 are 8.5 to 10.5 rps
E	30.0	28.17 rps max. 27.47 rps min.	Limits in rps are 25.5 to 31.5 - Actual rps given from T-5 to loss of signal from the Cape.

* The usual dropout at staging occurred. Duration was one second.

maintained throughout powered flight. Fuel cutoff and vehicle destruct commands were not sent, nor was either command inadvertently generated by the system.

AGENA VEHICLE SYSTEM PERFORMANCE

Structure System

Summary. - The structure system's performance was satisfactory.

Description. - The structure system consists of four major sections: the forward rack, the tank section, the aft rack, and the booster adapter. The forward rack, constructed of beryllium and aluminum, houses most of the electrical, guidance and communication equipment, and provides the mechanical and electrical interface for the spacecraft and shroud. The five-foot diameter tank section is composed of two integral aluminum propellant tanks, with a sump below each tank for engine start and propellant feed. The aft rack consists of a cone structure which supports the rocket engine and associated equipment. The magnesium alloy booster adapter supports the Agena and remains with the Atlas at separation.

For the ATS-1 Agena, the basic structure was modified by replacing the forward rack's beryllium panels with magnesium panels, and adding mountings for peculiar electrical, guidance and control, communication and control, and shroud system equipment. The panels were replaced because test results indicated that shroud loads transferred to the forward rack might cause fracture of the beryllium.

Performance. - The measured flight loads on the structure systems were within their expected range. The peak longitudinal load factor during flight was 6.1 g at BECO.

A summary of the flight dynamics data is presented in table XII. An analysis of the dynamic flight data appears in this report as Appendix D.

Shroud System

Summary. - ATS-1 was the first flight of the SAC shroud system. The shroud separated successfully after its pyrotechnics were fired at T+369.3 sec. All shroud parameters measured during the flight were within acceptable limits.

Description. - The shroud system consists of the SAC shroud with minor mission peculiar modifications incorporated. This was the first flight of the SAC shroud system, which was developed by LeRC to provide a standard payload shroud for several Agena missions. As shown in figure 10,

TABLE XII. - VIBRATION DATA SUMMARY

EVENT	TIME FROM LIFTOFF (SEC)	ACCELEROMETERS (STATION 247)						VIBR.PICKUPS (STATION 223)			
		CHANNEL 9 TANGENTIAL		CHANNEL 11 TANGENTIAL		CHANNEL 8 LONGITUDINAL		CHANNEL 17 LONGITUDINAL		CHANNEL 18 RADIAL	
		FREQ (Hz)	g (0-P)	FREQ (Hz)	g (0-P)	FREQ. (Hz)	g (0-P)	FREQ (Hz)	g (0-P)	FREQ. (Hz)	g (0-P)
LIFTOFF 02:12:00.876 EST	0	6	0.3	6	0.3	5	0.2	1000	9.0	1200	6.0
Transonic	39-59	150	0.5	200-400	0.2	100	0.4	1000	14.0	1000	9.6
Booster Eng. Cutoff (BECO)	129.1	130	0.5	120	0.4	12.0	0.5	---	---	50	0.3
Sustainer Eng Cutoff (SECO)	293.0	---	---	---	---	20	0.3	---	---	50	0.4
H/S Fairing Jettison	312.9	100	0.6	200	2.1	0.040 Sec Pulse	6.0	2000	18.0	2000	13.0
Atlas/Agena Separation	315.1	120	0.2	180	0.4	0.020 Sec Pulse	3.0	900	22	900	19
First Agena Ignition	359.2	55	0.2	50	0.3	80	0.4	700	1.8	55	0.6
Shroud Separation	369.3	80	0.2	550	0.4	40	0.4	1000	22	1000	23
First Agena Burnout	521.7	80	0.5	40 320	0.3 0.3	70	0.4	30-40	1.0	50	1.5
Second Agena Ignition	1171.4	80	0.5	130-240	0.5	75	0.4	1200	2.0	50	1.8
Second Agena Burnout	1248.7	45-120	0.5	140	0.7	65	0.4	900	3.0	50	2.0

the SACS system includes a transition ring; and two shroud halves forming a fairing having a cylindrical section 65 inches in diameter, a 15 deg half-angle cone and a 12-inch radius hemispherical dome. The total shroud system weight for ATS-1 is 723 lb. The two longitudinal halves are made of fiberglass strengthened by internal aluminum longerons and ribs. The halves are held together by a nose latch, two flat bands around the cylindrical section, and a V-band at the base of the cylinder.

The V-band clamps the shroud to the two-inch high aluminum transition ring, which is bolted to the Agena forward rack. The top, middle and bottom V-bands are tensioned to 5000, 2600 and 8000 lbs respectively. The spacecraft adapter is mounted to the top surface of the transition ring at Agena station 245. A metal diaphragm across the bottom of the transition ring is used to isolate the shroud compartment from the Agena. The shroud is vented through four ascent vent ports located in the cylindrical portion of the shroud (see fig. 10). The ascent vent ports are designed to permit venting only in an outward direction. The Agena is vented through holes in its aft equipment area which permit inward as well as outward flow.

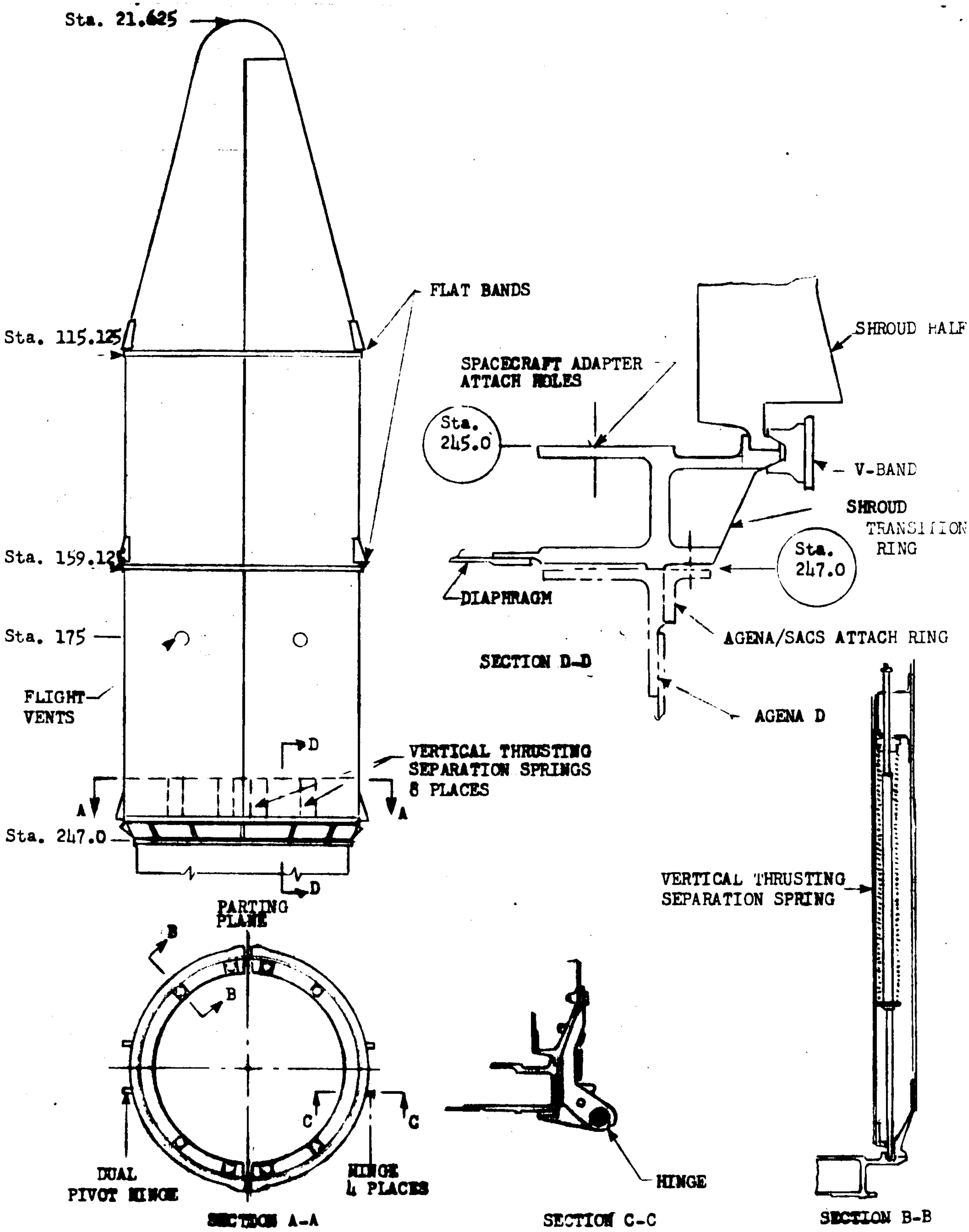
Figure 11 shows an ATS composite spacecraft mounted on the transition ring with one shroud half installed.

The shroud is instrumented with two temperature transducers on the inner surface of the shroud fiberglass skin at Agena vehicle station 176, and with one transducer to measure the pressure differential across the diaphragm.

Approximately ten seconds after the initiation of Agena first burn, shroud jettison is initiated. At this time, the Agena fires two pyrotechnic bolt cutters in the nose latch assembly and two explosive bolts in each of the bands. Springs at the base of the shroud then force the halves to rotate about hinges mounted on the transition ring. After the center of gravity of each shroud half has rotated over its hinge point, the Agena vehicle acceleration increases the shroud halves' rotation rate. In the one g acceleration field provided by the Agena at the time of shroud separation, each shroud half leaves the hinge and falls free of the vehicle after having rotated approximately 75 deg. The shroud separation springs have enough energy to jettison the shroud halves during a vehicle longitudinal acceleration up to 3.5 g.

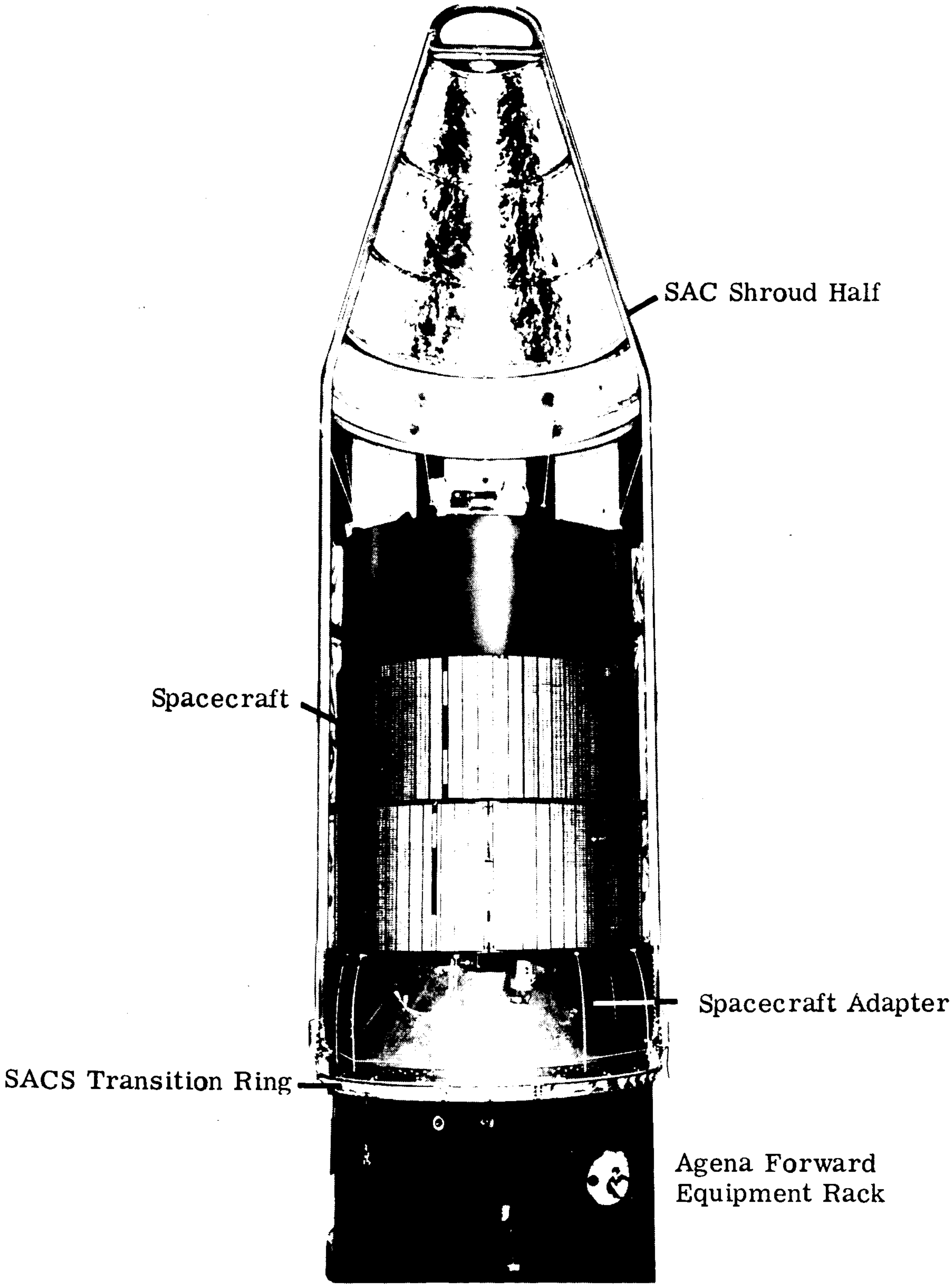
The spacecraft "encapsulation" concept was used on ATS-1. The complete shroud system and ATS-1 spacecraft were mated together in an environmental/explosive safe area. The spacecraft/shroud assembly (encapsulated spacecraft) was then transported to the launch pad and mated to the Agena as a unit.

<u>Performance</u>. - The inside skin temperature history is shown in figure 12. The peak temperature measured was 192° F, which was well within the maximum predicted temperature of 380° F for a 3 sigma depressed trajectory.



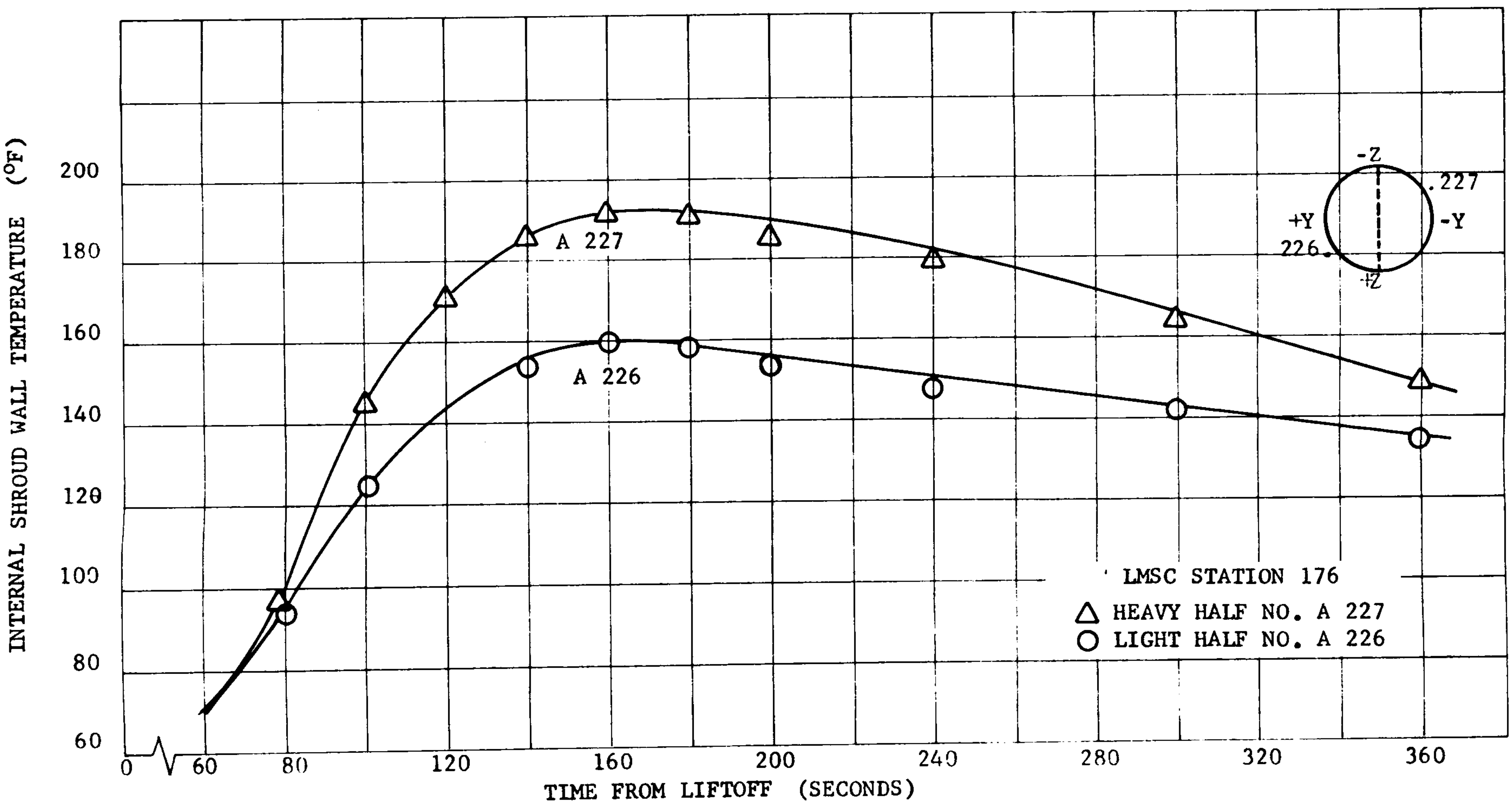
STANDARD AGENA CLAMSHELL SHROUD

FIGURE 10



ATS SHROUD/SPACECRAFT

FIGURE 11



ATS-1 INTERNAL SHROUD WALL TEMPERATURE VERSUS TIME FROM LIFTOFF

FIGURE 12

The differential pressure measured across the shroud diaphragm in flight is shown in figure 13. The differential pressure was essentially zero during the early portion of the flight. During the transonic phase, a differential pressure of -0.8 psi developed (a shroud cavity pressure less than the pressure in the Agena forward equipment section results in a negative pressure differential). After the transonic phase, differential pressure became slightly positive for a short period and then returned to essentially zero for the remainder of the flight. The differential pressure of -0.8 psi was due to the development of shock waves on the vehicle.

Shroud pyrotechnics were fired at T+369.3 sec, at which time the vehicle roll, yaw and pitch rates were very nearly zero. Jettison started 21 milliseconds later, as determined by the discontinuity of instrumentation data fed through electrical connectors on the shroud halves, which separate after first motion of the shroud halves. This time lag is comparable to the lag observed in ground tests of the SAC shroud. Total shroud jettison time after pyro firing should be 1.65 sec on the basis of ground tests. Using the time that the Agena horizon sensors detected interference caused by the shroud momentarily blocking the field of view of these infrared sensors, it was possible to verify that the actual jettison time was approximately 1.65 sec.

No measurable Agena roll, pitch or yaw rates developed as a result of shroud jettison.

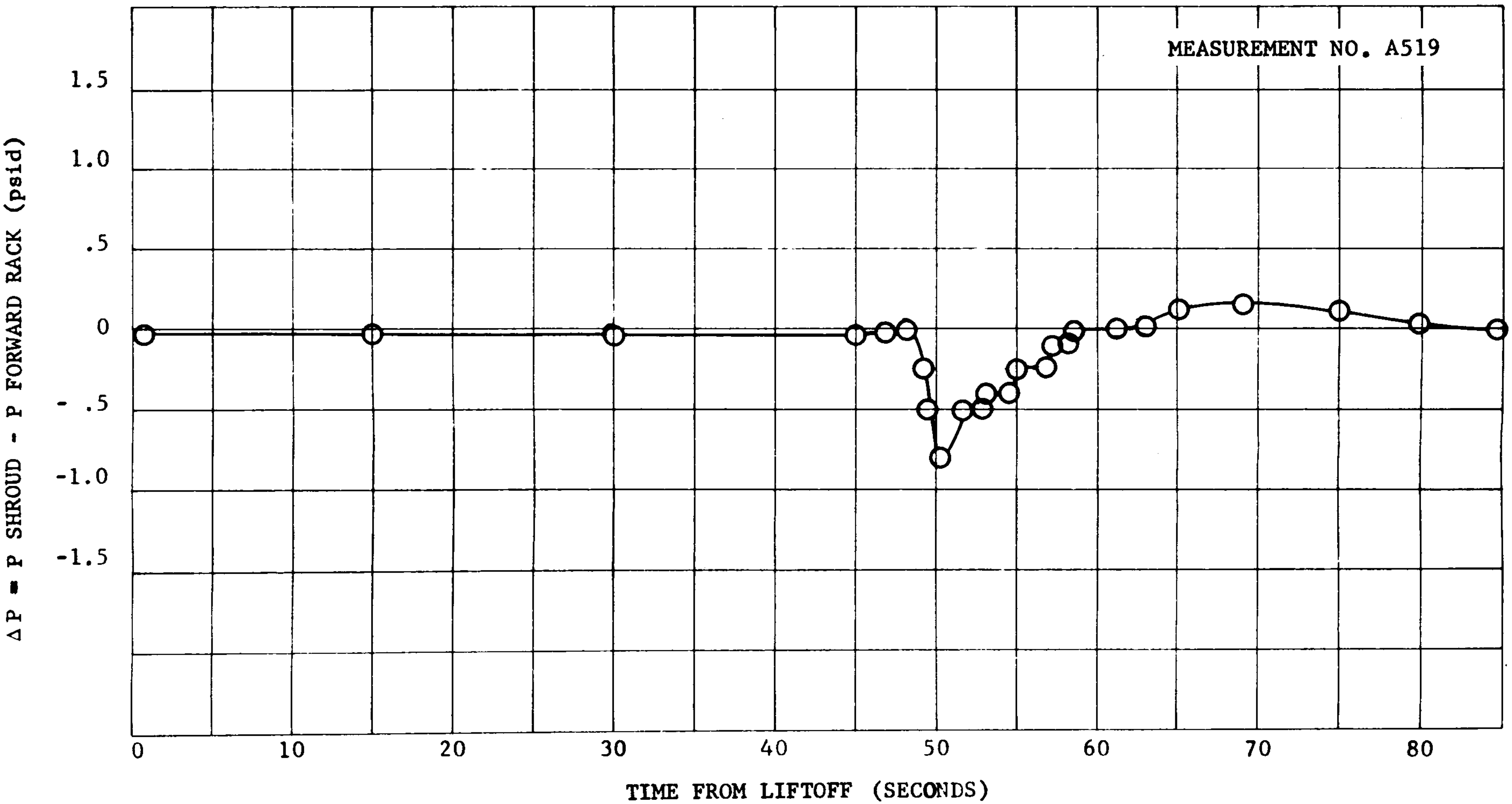
Propulsion System

Summary. - The propulsion system's performance was satisfactory, except for a momentary drop in chamber pressure during the second burn period, and the system provided the required impulse for orbital boost. Normal operation of the pressurization system and pyrotechnic devices was verified.

Description. - The propulsion system consists of a rocket engine, propellant pressurization system, booster adapter retrorockets, and vehicle pyrotechnics.

The engine has a regeneratively cooled combustion chamber mounted in a gimbal ring that is swiveled by hydraulic actuators. The engine, which burns unsymmetrical dimethylhydrazine (UDMH) fuel and inhibited red fuming nitric acid (IRFNA) as an oxidizer, generates a thrust of 16 000 lb in vacuum.

Sumps contain propellants for engine start after zero g coast. The propellant pressurization system provides sufficient helium gas pressure in both propellant tanks to ensure satisfactory engine operation. Tank pressure is achieved by allowing helium to flow from a high pressure



DIAPHRAGM DIFFERENTIAL PRESSURE VERSUS TIME FROM LIFTOFF

FIGURE 13

storage sphere to each propellant tank through a pair of fixed flow control orifices. The booster adapter is separated from the Agena by the cutting action of a circumferential mild detonating fuse. Two retro rockets mounted on the booster adapter are used to separate the Atlas and booster adapter from the Agena. No modification was made to the Agena propulsion system for ATS-1.

Performance. - For Agena first burn, the primary sequence timer initiated the engine ignition sequence at T+359.23 ±0.02 sec by energizing the gas generator start charge igniter and closing the main power relay (MPR). Voltage levels on the engine switch group indicated a normal start sequence.

Ninety percent chamber pressure was attained 1.21 ±0.02 sec later, indicating a normal start transient. Engine shutdown was commanded by the velocity at T+521.71 ±0.02 sec, resulting in a first burn duration (90 percent chamber pressure to velocity meter cutoff signal) of 161.27 ±0.04 sec. The predicted burn time was slightly less. Closure of the propellant isolation valves after first burn engine shutdown was verified by the decay in pump inlet pressures.

For Agena second burn, the propellant isolation valves were opened two seconds prior to initiation of the engine start sequence, as evidenced by the increase in pump inlet pressures. Second burn engine ignition sequence was initiated at T+1170.24 ±0.02 sec. Switch group voltage levels indicated a normal start sequence. Ninety percent chamber pressure was achieved 1.11 ±0.02 sec later, indicating a normal start transient.

Engine performance was nominal for approximately 7.6 sec after initiation of engine start sequence (MPR). At MPR + 7.6 sec, the chamber pressure was 506.5 psia, and at MPR + 8.34 sec, it reached a low value of 479.50 psia. A subsequent recovery was achieved: at MRP + 8.84 sec the chamber pressure was 505.00 psia, and at MPR + 10.29 sec it was 525.25 psia. This anomaly was also reflected in the turbine speed and in the oxidizer and fuel venturi inlet pressures. After the momentary drop, chamber pressure averaged 524.5 psia for the duration of the burn period. This pressure was 15.5 psia, or 3.0 percent, above the predicted value of 509 psia. This was the seventh Agena flight to experience a momentary decay in thrust out of approximately 140 flights. The exact cause of the anomaly is unknown at this time, but the primary suspect area is the turbopump on the Agena main engine. A comprehensive historical data search and turbopump test program has been initiated to determine the exact cause of this phenomenon. Engine shutdown was commanded by the velocity meter at 1248.69 ±0.02 sec after liftoff, resulting in a second burn duration (ninety percent chamber pressure to velocity meter cutoff signal) of 77.34 ±0.04 sec. The post flight nominal predicted burn time, was slightly longer.

The pressurization system's performance was satisfactory. Adequate pump inlet pressures were provided throughout the engine operation for both first and second burns.

Electrical System

Summary. - The electrical system's performance was satisfactory. All components operated well within specifications.

A number of the spacecraft separation squibs and the fast shutdown valve squib shorted during firing. The shorts were cleared by normal fusistor operation with no adverse effect to the vehicle.

Description. - The Agena electrical power system uses batteries and electrical control and conversion equipment to supply power to the vehicle systems.

Distribution circuits are provided for pyrotechnic power, main unregulated and regulated direct current power, and alternating current power.

For ATS-1, two Type VI-A batteries, each rated at 966 watt-hours, serve as the 28 volt power source for all equipment other than the flight termination system, which has its own batteries. Two fusistor junction boxes, a standard electrical junction box, and necessary wire harnessing were added to the Agena to supply power to the equipment peculiar to the ATS-1 Agena.

The Agena is equipped with an inverter which converts 28 volt battery power to 115 volts rms, either single or three phase, at 400 Hz, for the guidance system. In addition, a Type IX-A dc-dc converter provides a regulated voltage supply at $\pm$28.3 Vdc for the guidance systems.

Performance. - The electrical system voltage and currents were normal at liftoff and met the demands of the user systems throughout flight.

The main bus voltage was 25.5 Vdc at liftoff, and varied between 25.0 and 25.5 volts in flight. The main unregulated bus current was 15 amperes at liftoff, and varied between 10 and 16 amperes in flight. The pyrotechnic bus voltage was 27.0 Vdc at liftoff, and varied between 26.2 and 27.0 volts in flight.

The plus regulated dc voltage was constant at 27.6 volts, and the minus regulated dc voltage was constant at -28.3 volts throughout the flight. The inverter phase voltages were approximately 114.1 volts rms throughout the flight.

The structure current was zero except during the two Agena engine turn periods, when the current was 3 amperes, and during the momentary shorting of some squibs. These currents were within expected limits. The squib shorts were observed on the unregulated current monitor coincident with oxidizer Fast Shutdown and spacecraft separation squib firings. Both faults cleared without any adverse effect on vehicle performance. It is most probable that normal fusistor operation opened the circuit, clearing the shorts and preventing samage to the remainder of the system. Shorts such as these, although not desirable, are common to many squibs, and are encountered to some extent on all flights.

Guidance and Flight Control

Summary. - The guidance and flight control system's performance was satisfactory throughout flight. The system provided adequate control margins throughout flight with normal frequency response. All preprogrammed flight events were initiated within tolerance by the sequence timer. The sequence timer was started by the radio guidance discrete command 7.6 sec earlier than the nominal start time to compensate for trajectory dispersions; therefore, all subsequent timer events were approximately 7.6 sec earlier than their respective nominal times. A comparison of the nominal and actual times of major flight events is given in table I. A detailed sequence of flight events for ATS-1 is provided as Appendix A to this report.

Description. - The guidance and flight control system performs the vehicle guidance, control and flight programming functions necessary to accomplish the vehicle mission after Atlas/Agena separation. The system consists of three subsystems corresponding to the guidance, control and flight programming functions.

The guidance subsystem consists of an inertial reference package (IRP), horizon sensors, velocity meter, and guidance junction box. Primary attitude reference is provided by three orthogonal, rate integrating gyroscopes in the IRP. The infrared horizon sensors provide continuous corrections in pitch and roll to the IRP. Yaw attitude reference is obtained from the booster and is corrected by gyro-compassing techniques during long coast periods. The velocity meter counter generates a signal to terminate engine thrust when the vehicle has increased its velocity by a predetermined increment. Longitudinal acceleration is sensed by the velocity meter accelerometer, which counts down the first burn "velocity-to-be-gained" binary number in the counting register. The secong burn "velocity-to-be-gained" number is transferred from a storage register to the counting register after first burn cutoff.

The flight control subsystem, which controls the vehicle's attitude, consists of a flight control electronics unit, a pneumatic control system, a hydraulic control system, and a flight control junction box. Attitude error signals from the IRP are conditioned and amplified by the flight control electronics to operate the pneumatic and hydraulic systems. During Agena coast periods, the pneumatic system provides roll, pitch, and yaw control by use of six thrusters operating on a mixture of nitrogen and Freon. The hydraulic system provides pitch and yaw control during engine burn by means of two hydraulic actuators which gimbal the rocket engine thrust chamber. Roll control during engine burn is provided by the pneumatic system. A patch panel in the flight control junction box provides the means for varying the interconnections of the guidance and flight control system to suit mission requirements.

The flight programming subsystem uses sequence timers to program Agena flight events. A sequence timer provides 22 usable, discrete event times with multiple switch closure capability, and has a maximum running time of 6000 sec. Two timers (a primary and an auxiliary) are required if the Agena mission duration exceeds 6000 sec, or if more than 22 discrete events are required. The primary sequence timer is started by a radio guidance discrete command at a time determined by the actual trajectory of the booster. The auxiliary sequence timer is started by the primary timer.

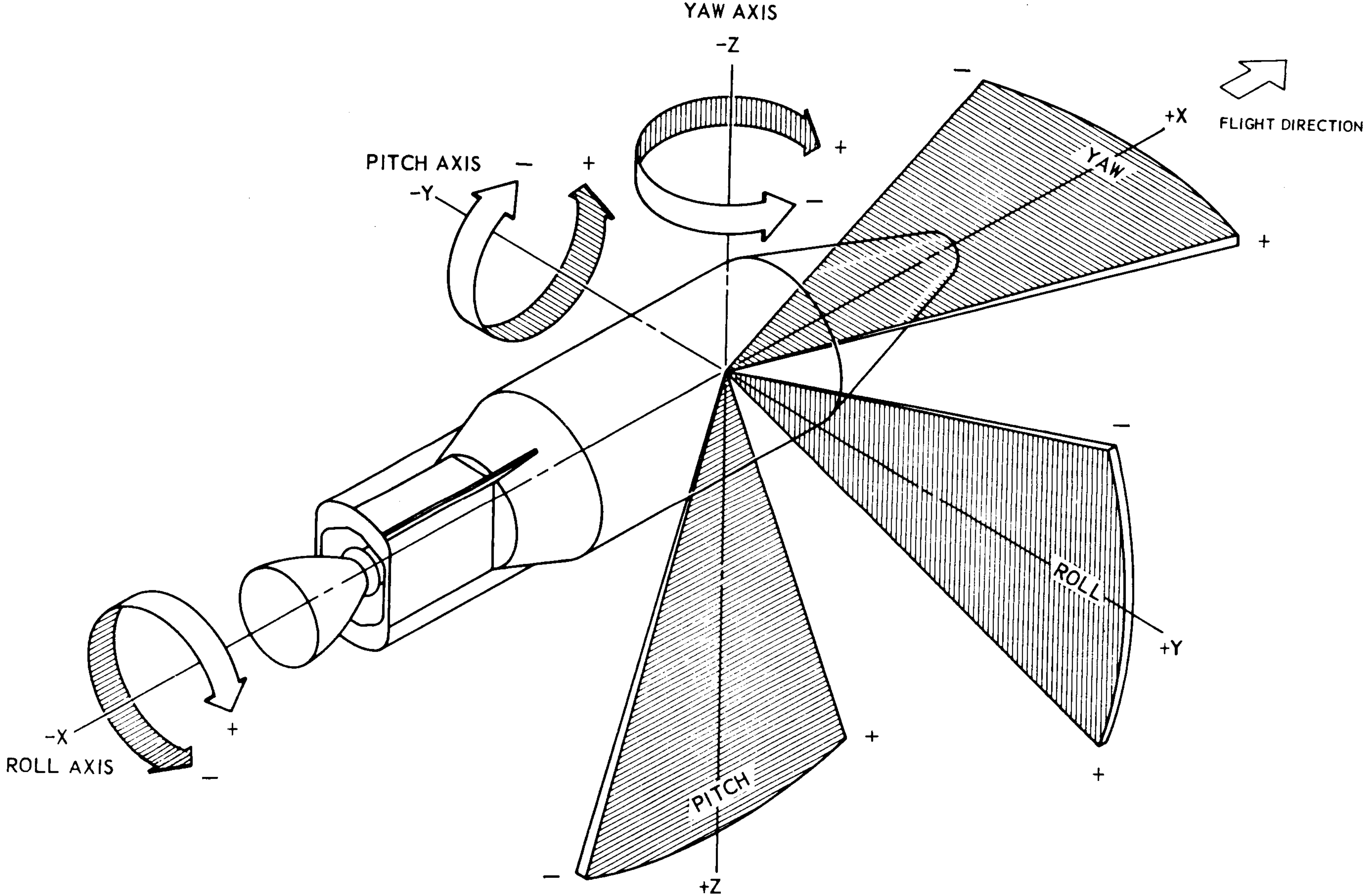
The ATS-1 Agena uses two sequence timers to program flight events. The sequence timers for all ATS Agena missions are wired to a common design which requires the use of two timers to accommodate the long coast periods of ATS missions subsequent to ATS-1.

Performance. - Analysis of post-flight data for the ATS-1 vehicle shows that Atlas/Agena separation induced Agena body rates of 0.1 deg/sec yaw left, 0.075 deg/sec roll CW, and 0.95 deg/sec pitch up. (Clockwise and counterclockwise roll reference applies when looking forward along the Agena longitudinal axis).(See fig. 14). These low rates, coupled with Atlas attitude errors, caused Agena attitude errors of 0.4 deg yaw left, 0.05 deg roll CCW, and 1.5 deg pitch up at pneumatics activation. Gas valve activity reduced these attitude errors to within the deadband limits of ±0.2 deg pitch, ±0.18 deg yaw and ±0.6 deg in roll in 4.5 sec.

Subsequent to pneumatic activation, the vehicle completed the programmed pitchdown of 10 deg, and the programmed geocentric rate of 3.21 deg/min pitchdown was applied. The pitch horizon sensor, set at a pitch bias angle of +5.10 deg (nose up) for first burn, was connected to the pitch gyro, and the vehicle was in the process of stabilizing in pitch at the time of first burn ignition.

Body rates of 0.18 deg/sec pitch up and 0.80 deg/sec roll CW existed at the time of engine ignition. No yaw errors were discernible from either position gyro or pneumatic activity data.

At first burn ignition, the gas generator turbine spin-up (coupled with the existing low CW roll rate) produced a roll rate that reached a



AGENA VEHICLE AXES AND VEHICLE MOVEMENT DESIGNATIONS

FIGURE 14

maximum of 0.95 deg/sec CW. This rate induced a maximum roll error of 1.6 deg CW. Roll pneumatic activity reduced the roll rate to zero in 1.6 sec, and the vehicle started to return toward the zero error position, overshot to 1.5 deg CCW (due to turbine exhaust duct misalinement torque), then returned to the edge of the roll dead-band with 0.2 deg CCW roll offset.

Hydraulic pressure buildup and off-null engine position introduced hydraulic transient responses in both the pitch and yaw channels. Peak overshoots of 0.3 deg yaw left and 0.5 deg pitchdown were evidenced approximately four seconds after engine start; however, these errors were reduced by hydraulic control, which had stabilized eight seconds after ignition.

Shroud jettison (initiated ten seconds after first burn ignition) occurred during the portion of the 1.5 deg CCW roll overshoot when the vehicle roll rate had reached a minimum (approx. zero). The horizon sensors indicated a slight disturbance approximately two seconds after shroud pyro firing; however, gyro data in roll and pitch indicate that little or no attitude error was introduced by shroud jettison. These disturbances are attributable to the shroud halves passing through the fields of view of the horizon sensors.

Hydraulic and pneumatic activity were normal throughout the burn period. Engine shutdown was commanded by the velocity meter after the vehicle attained the required velocity increment of 7231.49 fps. The additional velocity increment due to engine tailoff thrust was 6.9 fps.

A normal roll transient, caused by engine shutdown(i.e., turbine spin and turbine exhaust thrust decay), initiated a pneumatic system overshoot resulting in a 2.4 deg roll CCW excursion, which was reduced to within the pneumatic congrol system dead-band in five seconds.

The pneumatic attitude control system was transferred to the orbit (low pressure) mode; the programmed geocentric pitch rate was set to -4.5 deg/min; and the horizon sensor bias angle was decreased to zero. Transfer of the required second burn velocity increment (8078.4 fps) from the storage register to the counting register was performed satisfactorily.

Horizon sensor and pneumatics data show that the vehicle maintained the proper attitude in the coast phase with a minimum of pneumatic activity.

Second burn ignition induced roll rates which resulted in a maximum roll attitude error of 1.8 deg CW; these rates were satisfactorily damped by pneumatic control. The vehicle assumed a CCW roll offset of 0.2 deg in the same manner as that of first burn. Hydraulic control displayed a start up transient, resulting in a yaw actuator peak overshoot of 0.1 deg yaw left, which returned to zero in a normal time span.

Engine shutdown was commanded by the velocity meter after the vehicle attained the required velocity increment of 8078.4 fps. Thrust due to engine tailoff increased the velocity 27 fps prior to velocity meter counter disable.

A normal shutdown transient of 2.8 deg roll CCW was reduced to within the dead-band limits in 11 seconds. The vehicle then assumed a roll limit cycle rate of 0.03 Hz, which was within the expected average limit cycle rate.

The horizon sensors were disconnected from the gyros, and the vehicle pitched up 9.36 deg and yawed left 57 deg as programmed. The Agena was stable within the pneumatic dead-bands at the time of spacecraft separation.

After spacecraft separation, the vehicle completed a yaw right maneuver of 237 deg, which put the vehicle in the desired nose aft position. There was essentially no pneumatic activity required after the yaw, except for an occasional pulse to maintain the geocentric pitch rate.

The attitude control gas usage was less than anticipated. A comparison of the predicted and actual gas usage is given in Table XIV. These data indicate that no unusual attitude perturbing forces were encountered in flight.

Communications and Control

Summary. - The communication and control system's performance was satisfactory. All subsystem parameters measured during the flight were at the expected levels.

Description. - The communication and control system consists of telemeter, instrumentation, tracking, and flight termination subsystems and associated power supplies.

The telemeter subsystem is mounted in the forward equipment rack. It monitors and transmits the Agena functional and environmental condition measurements during ascent. The Type V FM/FM telemeter unit contains a VHF transmitter, voltage controlled oscillators, a commutator, a switch and calibrate unit, and a dc-dc converter. The transmitter operates on an assigned frequency of 244.3 mHz at a power output of 10 watts. The telemeter system has the capacity for 18 subcarriers using

TABLE XIV. - GUIDANCE GAS LOADING REQUIREMENTS AND USAGE

Flight Sequence	Predicted	Actual
Liftoff	29.7 lb Loaded	29.3 lb Loaded
First Agena Coast	5.7 lb Usage	3.2 lb Used
First Agena Burn	4.0 lb Usage	4.2 lb Used
Orbital Coast	0.6 lb Usage	0.4 lb Used
Second Agena Burn	2.4 lb Usage	2.1 lb Used
Pre S/C Sep. Maneuver	1.1 lb Usage	0.9 lb Used
Post S/C Sep. Maneuver	0.3 lb Usage	0.3 lb Used
Loss of Signal	15.6 lb Available	18.2 lb Available

the standard IRIG subcarrier channels. Channels 15 and 16 are commutated at 5 rps with 60 segments on each channel.

The telemetry is turned off during the coast period between first and second burn, even though the ATS-1/Agena did not require the shutdown, because one common vehicle configuration was developed for all ATS Agenas. In order to conserve power and prevent the transmitter from overheating on ATS flights after ATS-1, the sqeuence timer is configured to shut off the telemetry system during the coast period between first and second burn.

The instrumentation subsystem consists of 57 transducers and event monitors. Five continuous subcarrier channels are used for accelerometer data; one carries the gas valve current signals, and another is time shared by the velocity meter accelerometer and velocity meter counter.

The turbine speed signal does not use a subcarrier channel, but directly modulates the transmitter during engine operation. The remaining 48 measurements are monitored on the two commutated subcarrier channels. The transducers are powered by a regulated 28 Vdc power supply located in the telemeter unit. A complete list of transducers flown is given in Appendix E.

The tracking subsystem includes a C-band radar transponder (C-band beacon), RF switch, and antenna. The C-band beacon received coded signals from the tracking radar on a carrier frequency of 5690 mHz, and transmits coded responses on a carrier frequency of 5765 mHz at a minimum peak power output of 200 watts at the input terminals of the antenna. The coded responses are at pulse rates (pulse repetition frequency) from 0 to 1600 pulses per second. The pulse rate varies inversely with range. The RF switch, which had not been used on previous NASA Agenas, connects the output of the beacon to either the umbilical for ground checkout or the antenna for flight.

For reasons similar to those given above for the telemetry system, the C-band beacon is turned off during the coast period between first and second burn.

The flight termination subsystem provides a range safety flight termination capability for the Agena from liftoff through Agena first burn cutoff. This subsystem consists of two receiver-decoders which are coupled to two antennas by a multicoupler, two Type V secondary batteries, two destruct initiators. and a destruct charge. These units are connected so as to provide redundant flight termination capability, with the exception of the multicoupler and destruct charge, which are not redundant. Flight termination, if necessary, is initiated by series of commands from the range safety transmitter. The first sequence of commands shuts down the engine, the second sequence of commands fires the destruct charge. The destruct charge, located in the -Z axis lontigudinal tunnel near the fuel oxidizer bulkhead, ruptures both propellant tanks and effects dispersion of the propellants.

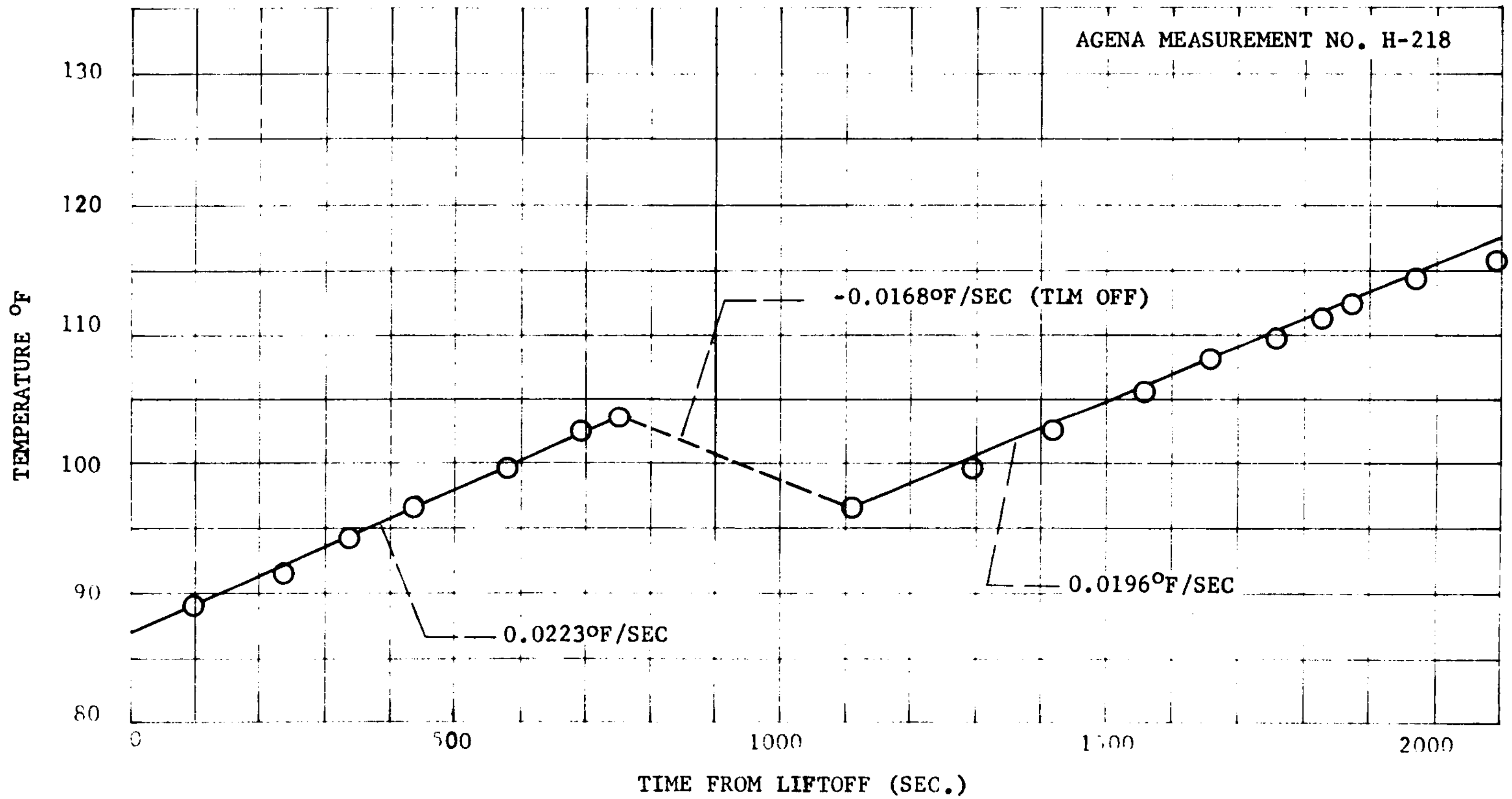
Performance. - The telemeter subsystem's performance was satisfactory throughout the flight. Station 9.1 (Antigua) and the Range Instrumentation Ship (RIS) Twin Falls, monitoring first and second burn phases of the mission, respectively, recorded a good TLM signal strength of at least 80 micro-volts throughout these phases. The Antigua signal strength data showed that TLM was turned off at T+753.3 sec, and the RIS Twin Falls signal strength data showed that TLM was turned back on at T+1110.3 sec. The received signal at the Twin Falls was adequate for the surface equipment to produce data within one second of TLM turn on time. In-flight calibrations and instrumentation data indicate that the TLM subsystem resumed normal operation after TLM turn on. A description of the tracking and data acquisition network used in support of the ATS-1 flight is given in Appendix C.

The in-flight operating period of the TLM subsystem was 1820.2 sec. During flight operation, the temperature of the TLM subsystem transmitter rose, from a liftoff temperature of 85° F, to 117° F.

Examination of the graph in figure 15 (Transmitter Temperature against Time) reveals that the highest rate of temperature rise during flight was approximately 0.0223° F per second. Assuming this rate of increase as a worst case condition, the transmitter would have had 3578 sec of operating time before reaching its maximum operating temperature of 160° F. These data indicate a lower rate of transmitter temperature rise than was predicted.

The instrumentation subsystem functioned normally during the vehicle flight. The peculiar and standard instrumentation flown are tabulated in Appendix E. Usable data was obtained from all vehicle measurements. Flight data of channels 17 and 18 indicate that the wire harnesses for Longitudinal Vibrometer A520 and Radial Vibrometer A524 were interchanged. Therefore, the flight dynamics data for the Longitudinal Vibrometer A520 were transmitted over channel 17 instead of channel 18, and the data for the Radial Vibrometer A524 were transmitted over channel 18 instead of channel 17. The flight dynamic data shown in Appendix D reflect the "as flown" configuration.

The A520 and A524 vibrometers were located near a spacecraft separation pyro device. The spacecraft separation pyro shock caused both transducers to saturate their amplifiers. Approximately 10 sec were required for the resulting 2 Hz sinusoidal transient to damp out, after which normal response was restored with no known permanent damage incurred.



TELEMETRY TRANSMITTER TEMPERATURE VERSUS TIME

FIGURE 15

All operational signals from the instrumentation event monitors and calibration signals were on time and of the proper magnitude.

The tracking subsystem's performance was satisfactory throughout the flight. The C-band beacon was turned off for 351 sec during the coast period between first and second burn. Continuous interrogation was recorded during the first period of operation, with normal interrogation and transponder rates. The first interrogation of the C-band beacon, after it was turned back on at T+1104.3 sec, was from the RIS Twin Falls at T+1235.7 sec. During this second period of operation, normal interrogation and transponder rates indicated the proper operation of the C-band beacon.

Both flight termination receivers functioned satisfactorily during prelaunch tests and flight. The received signal strength remained well above the airborne receiver threshold of 2 microvolts through first burn. At liftoff, both receivers indicated a received signal strength greater than 20 microvolts. Just prior to disabling the flight termination subsystem at T+544.3 sec, the received signal strengths were approximately 7 microvolts. These data indicate that the vehicle was receiving adequate signal strength for the operation of the flight termination subsystem if termination had been required.

LAUNCH OPERATIONS

Prelaunch Activities

The Atlas, Agena and Spacrcraft arrived at AFETR September 21, October 17 and October 31, 1966, respectively. A calendar of major activities at ETR is shown in table XV. All prelaunch tests were completed satisfactorily. The significant schedule delays and test malfunctions which occurred during the prelaunch period were as follows:

1. Atlas erection was delayed one day due to misalinement between the launcher and the vehicle.

2. Atlas dual propellant loading was attempted November 7, with the following problems occurring:

   a. A leak developed in the booster engine No. 1 fuel pump inlet pressure transducer boss, necessitating replacement of the boss Toro seal.

   b. A leak developed at the aft flange of the fuel staging valve, resulting in the replacement of the flange seal.

   c. The booster engine No. 2 fuel drain disconnect leaked and was replaced.

TABLE XV. - PRELAUNCH ACTIVITY

Date	Event
October 12, 1966	Booster Erection
October 27, 1966	B-Fact No. 1
November 8, 1966	Booster Dual Propellant Loading (DPL) Test
November 16, 1966	B-Fact No. 2
November 23, 1966	Vehicle Systems/AGE Compatability Checks Completed
November 28, 1966	Radio Frequency Interference (RFI) Test
November 29, 1966	J-Fact
December 1, 1966	J-Fact (Agena only)
December 2, 1966	Simulated Launch Demonstration (SLD)

3. Immediately after power application to the Agena during radio-frequency interference (RFI) testing November 28, high current readouts were noted in the Launch Operations Building. The excessive currents resulted from an electrical short caused by an AGE wiring error. As a consequence, a diode was damaged in the Agena flight control junction box which required the junction box to be replaced by a spare. Acceptability of the replacement junction box was verified by special test on stand.

4. Because of anomalies in the C-band beacon data obtained from the umbilical hardline connections to the Agena, the C-band beacon checks during prelaunch tests and during countdown for launch were performed utilizing the RF "hat" coupler. Replacement of a portion of the umbilical tower coaxial cable, subsequent to the launch, corrected the difficulty. The cable was found to have a low resistance between its shield and primary conductor, which resulted in excess signal loss.

Countdown and Launch

The ATS vehicle was successfully launched on the first attempt. The launch vehicle countdown was initiated at T-425 min (approximately 1307 hours, EST, December 6, 1966) with planned holds of 55 min at T-60 min and 5 min at T-7 min. The countdown was completed without unplanned holds.

Liftoff occurred at 2112:01.046 EST as indicated by the 8-inch motion switch.[(1)] The 2-inch motion switch malfunctioned, and an estimated time of 0.170 seconds between 2-inch and 8-inch motion was used throughout this report to arrive at a 2-inch liftoff time (T-0) of 2112:00.876 EST. All other AGE systems operated satisfactorily during countdown and liftoff.

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(1) Per reference 6.

APPENDIX A

SEQUENCE OF FLIGHT EVENTS

APPENDIX A. - ATS-1 SEQUENCE OF EVENTS

Nominal Time (sec) (1)	Actual Time (sec)	Event Description	Source	Event Monitor (2)
0	0	Liftoff (2112:00.876 EST)		2" Motion Switch (M3CX) (3)
129	129.1	Atlas Booster Cutoff	Atlas Guidance	Longitudinal Acc.(U101A)
293.1	293.0	Atlas Sustainer Cutoff	Atlas Guidance	Longitudinal Acc(U101A)
295.8	288.2	Start Agena Timer	Atlas Guidance	G&C Monitor (D14)
312.8	312.9	Atlas Vernier Cutoff	Atlas Guidance	Longitudinal Acc.(U101A)
		Uncage Agena Gyros		
		Jettison H/S Fairing		
		Arm Atlas/Agena Separation		
315	315.1	Atlas/Agena Separation	Atlas Guidance	G&C Monitor (D14)
317.5	317.4	Activate Pneumatics	Sep. Switch	G&C Monitor (D14)
		Connect Roll H/S to Roll Gyro		
341.8	334.2	Initiate -120°/min Pitch rate	Primary Timer	Pitch Torque Rate (D73)
346.8	339.1	Transfer to -3.21°/min Pitch Rate	Primary Timer	Pitch Torque Rate (D73)
		Connect Pitch H/S to Pitch Gyro		
		Connect V/M Accel. Output to TLM		
366.8	359.2	Fire First Burn Ignition Squibs	Primary Timer	Switch Group Z (B31)
		Deactivate Pitch and Yaw Pneumatics		
		Enable V/M		
368	360.4	Agena Steady State Thrust		Chamber Pressure (B91)
368.3	360.7	Fire He Pressure Squibs	Primary Timer	
376.8	369.3	Fire Shroud Squibs	Primary Timer	Shroud Separation (A52) (4)
511.8	504.3	Arm Engine Shutdown	Primary Timer	
		Arm Command Destruct Disarm		

528.1	521.7	Agena Engine Cutoff Activate P&Y Pneumatics Fire Ox. Fast Shutdown Squib	V/M	V/M Acc.-Counter (D83/D88)
534.8	527.2	Remove 28V from P&Y Pneumatics Start TLM Calibration Connect V/M Counter Output to TLM Close PIV	Primary Timer	V/M Acc.-Counter (D83/D88)
551.8	544.3	Stop TLM Calibrate & Disarm Command Destruct Pneumatics to Low Pressure Attenuate H/S Gains for P&R Start Gyrocompassing Transfer to -4.46°/min Pitch Rate	Primary Timer	Pitch Torque Rate (D73)
556.8	549.3	Fire H/S Zero Deg. Squib Transfer to Second Burn Delta V	Primary Timer	V/M Acc.-Counter (D83/D88)
758.8	751.3	Fire Close He Valve Squib Start Auxiliary Timer	Primary Timer	(4)
760.8	753.3	Stop Primary Timer Turn TLM Off Beacon Power Off	Auxiliary Timer	TLM Signal Strength
1111.8	1104.3	Start Primary Timer Beacon Power On	Auxiliary Timer	(4)
1117.8	1110.3	Turn TLM On	Primary Timer	TLM Signal Strength
1118.8	1111.3	Pneumatics to High Pressure Remove Gyrocompassing	Primary Timer	(4)
1175.8	1168.3	Connect Accel.Output to TLM Enable V/M Open PIV	Primary Timer	V/M Acc.-Counter (D83/D88)
1177.8	1170.3	Deactivate P&Y Pneumatics Fire Second Burn Ignition Squibs	Primary Timer	Switch Group Z (B13)

1179	1171.4	Agena Steady State Thrust		Chamber Pressure (B91)
1253.8	1246.3	Arm Engine Shutdown	Primary Timer	(4)
1258	1248.7	Agena Engine Cutoff P&Y Pneumatics On	V/M	V/M Acc.-Counter (D83/D88)
1261.8	1254.3	Connect V/M Counter Output to TLM Start TLM Calibrate	Primary Timer	V/M Acc.-Counter (D83/D88)
1266.8	1259.3	Stop TLM Calibrate Connect Accel. Output to TLM Start Auxiliary Timer	Primary Timer	V/M Acc.-Counter (D83/D88)
1334.8	1327.3	Transfer to +28.1°/min Pitch Rate Disconnect H/S Inputs from P&R Gyro	Auxiliary Timer	Pitch Torque Rate (D73)
1354.8	1347.3	Stop 28.1°/min Pitch Rate	Auxiliary Timer	Pitch Torque Rate (D73)
1364.8	1357.2	Initiate -180°/min Yaw Rate	Auxiliary Timer	Yaw Torque Rate (D51)
1383.8	1376.4	Stop -180°/min Yaw Rate	Auxiliary Timer	Yaw Torque Rate (D51)
1394.8	1387.4	Fire Spacecraft Separation Squibs	Primary Timer	Longitudinal Vibration (A520)
1397.8	1390.3	Initiate +180°/min Yaw Rate	Primary Timer	Yaw Torque Rate (D51)
1476.8	1469.3	Stop +180°/min Yaw Rate	Primary Timer	Yaw Torque Rate (D51)
1476.8	1469.3	Initiate +3.7°/min Pitch Rate Connect H/S Inputs to P&R Gyro	Auxiliary Timer	Pitch Torque Rate (D73)
1496.8	1489.3	Pneumatics to Low Pressure Attenuate H/S Gains in P&R Start Gyrocompassing	Auxiliary Timer	Yaw Torque Rate (D51)
2124.8	2117.3	Pneumatics to High Pressure Remove Gyrocompassing	Auxiliary Timer	Yaw Torque Rate (D51)

2184.8	2177.3	Remove all Power from Vehicle except C-Band Beacon	Auxiliary Timer	TLM Signal Strength

(1) Obtained from reference 2.

(2) The first three and fifth events are monitored on Atlas TLM; the remaining on Agena TLM. The designation in parentheses is the Monitor Measurement designation. See the Atlas and Agena Telemetry Schedules (Appendixes C and E, respectively) for the measurement range and channel assignment.

(3) Per reference 4, liftoff occurred at 2112.01.046 hours EST as indicated by the 8-inch motion switch. The 2-inch motion switch malfunctioned and a nominal time of 0.170 seconds between 2-inch and 8-inch motion was used throughout this report for a computed 2-inch liftoff time of 2112:00.876 hours EST. All nominal trajectory times are referenced to the 2-inch motion liftoff.

(4) No direct measurement for these events.

APPENDIX B

ATLAS

TELEMETRY INSTRUMENTATION SCHEDULE

APPENDIX B

ATLAS TELEMETRY INSTRUMENTATION SCHEDULE

Meas. No.	Description	Channel Assignment (1)	Meas. Range Low/High (2)
A743T	AMB TEMP AT SUS INST PANEL	11-41	-50/550° F
A745T	AMB TEMP AT SUS FUEL PUMP	11-45	-50/550° F
D1V	RSC CUTOFF OUTPUT	5-5	---
D1V	RSC CUTOFF OUTPUT	15-1	0/5 VDC
D1V	No. 1 RSC RF INPUT/AGC	15-3	0/10K UV
D3A	RSC DESTRUCT OUTPUT	16-S	0/6 VDC
E28V	MAIN DC VOLTAGE	18-1/31	20/35 VDC
E51V	400 CYCLE AC PHASE A	18-11	105/125 VDC
E52V	400 CYCLE AC PHASE B	18-29	105/125 VAC
E53V	400 CYCLE AC PHASE C	18-41	105/125 VAC
E95V	28VDC GUID POWER IN	13-15	20/35 VDC
E96V	115 VAC 400 TQ RF PHASE A	13-37	105/125 VAC
E151V	400 CYCLE PHASE A WAVEFORM	10	0/150 VAC
F1P	LOX TANK HELIUM	15-9	0/50 PSIA
F3P	FUEL TANK HELIUM	15-11	0/100 PSIA
F116P	DP ACROSS BULKHEAD	18-13/43	0/25 PSID
F125P	BOOSTER CONTROL PNEU REG OUT	13-21	0/1000 PSIA
F246P	BOOSTER TANK HELIUM BOTTLE	13-55	0/3500 PSIA
F288P	START PNEUMATIC REG OUT	13-1	0/800 PSIA
F291P	SUSTAINER CONTROL HE BOTTLE	13-3	0/3500 PSIA
F247P	BOOSTER TANK HE BOTTLE TEMP	11-31	-400/-250° F
G4C	PULSE BEACON MAGNETRON AVERAGE	15-15	0/5 VDC
G82E	RATE BEACON RF OUTPUT	15-17	0/5 VDC
G3V	PULSE BEACON AGC	15-19	0/5 VDC
G279V	RATE BEACON AGC NO. 1	15-21	0/5 VDC
G280V	RATE BEACON AGC NO.2	15-13	0/5 VDC
G282V	RATE BEACON PHASE DETECTOR NO. 1	15-45	0/5 VDC
G287V	DECODER PITCH OUTPUT	15-47	0/5 VDC
G288V	DECODER YAW OUTPUT	15-49	0/5 VDC
G296V	PULSE BEACON 15 VDC POWER SUPPLY	13-9	0/5 VDC
G298V	DECODER 10 VDC POWER SUPPLY	13-13	0/5 VDC
G354V	RATE BEACON 25/30 VDC PWR SUP	13-11	0/5 VDC
G590V	DISCRETE BINARY 1	16-33	0/5 VDC
G591V	DISCRETE BINARY 2	16-35	0/5 VDC
G592V	DISCRETE BINARY 4	16-37	0/5 VDC

G593V	DISCRETE BINARY 8	16-39	0/5 VDC
H3P	BOOSTER HYD PUMP DISCHARGE PRESS	13-41	0/3500 PSIA
H33P	B1 HYD ACCUMULATOR PRESSURE	15-31	0/3500 PSIA
H130P	SUSTAINER HYD PUMP DISCH PRESS	15-33	0/3500 PSIA
H140P	SUST/VERNIER HYD PRESSURE	15-35	0/3500 PSIA
H224P	BOOSTER HYD SYS LOWPRESS	15-7	0/600 PSIA
H601P	SUSTAINER HYD RETURN LINE	18-7/37	0/600 PSIA
M79A	MISSILE AXIAL ACCEL FINE	7	-.5/.5 G
M30X	MISSILE 2-INCH MOTION	7-S	----
M32X	CONAX VALVE COMMAND	5-S	----
P83B	BOOSTER 2 PUMP SPEED	15-41	4000/7000 RPM
P84B	BOOSTER 1 PUMP SPEED	4	6000/6950 RPM
P349B	SUSTAINER PUMP SPEED	3	9.9/11.2 KPM
P529D	SUSTAINER MAIN LOX VALVE	13-43	0/90 Deg.
P830D	SUSTAINER FUEL VALVE POSITION	13-35	0/30 Deg.
P1P	BOOSTER 1 LOX PUMP INLET PRESS	18-9	0/150 PSIA
P2P	BOOSTER 1 FUEL PUMP INLET PRESS	13-31	0/100 PSIA
P6P	SUSTAINER THRUST CHAMBER PRESS	18-3/33	0/1000 PSIA
P26P	BOOSTER LOX REG REFERENCE	13-17	500/1000 PSIA
P27P	VERNIER FUEL TANK PRESS	13-39	0/1000 PSIA
P28P	VERNIER 1 THRUST CHAMBER PRESS	18-15	0/400 PSIA
P29P	VERNIER 2 THRUST CHAMBER PRESS	18-17	0/400 PSIA
P30P	VERNIER LOX TANK PRESSURE	13-53	0/1000 PSIA
P47P	VERNIER 1 LOX INLET PRESS	13-45	0/600 PSIA
P49P	VERNIER 1 FUEL INLET PRESS	13-49	0/600 PSIA
P55P	SUSTAINER FUEL PUMP INLET PRESS	13-5	0/100 PSIA
P56P	SUSTAINER LOX PUMP INLET PRESS	18-5	0/150 PSIA
P59P	BOOSTER 2 THRUST CHAMBER PRESS	18-19	0/800 PSIA
P60P	BOOSTER 1 THRUST CHAMBER PRESS	18-21	0/800 PSIA
P100P	B GAS GEN COMBUSTION CHM PRESS	15-51	0/600 PSIA
P330P	SUSTAINER FUEL PUMP DISCH PRESS	15-55	0/1500 PSIA
P339P	SUSTAINER GAS GENERATOR DISCH PRESS	18-55	0/800 PSIA
P344P	SUSTAINER LOX REG REFERENCE	13-19	500/1000 PSIA
P15T	ENG COMPARTMENT AIR TEMP	11-35	-50/550° F
P16T	ENGINE COMP COMPONENT TEMP	11-55	0/400° F
P117T	BOOSTER 2 FUEL PUMP INLET	11-53	0/100° F
P530T	SUS LOX PUMP INLET TEMP	11-1	-300/-270° F
P671T	THST SECT AMB TEMP QUAD 4	11-15	-50/550° F
P77X	VERNIER CUTOFF RELAY	8-S	----
P347X	SYST CUTOFF RELAY	8-S	----
P616X	BOOSTER FLIGHT LOCKIN	16-19	----
S61D	ROLL DISPL GYRO SIGNAL	15-29	-3/3 Deg.

S62D	PITCH DISPL GYRO SIGNAL	15-37	-3/3 Deg.
S63D	YAW DISPL GYRO SIGNAL	15-39	-3/3 Deg.
S252D	BOOSTER 1 YAW ROLL	16-15	-6/6 Deg.
S253D	BOOSTER 2 YAW ROLL	16-55	-6/6 Dg.
S254D	BOOSTER 1 PITCH	7	-6/6 Deg.
S255D	BOOSTER 2 PITCH	16-1	-6/6 Deg.
S256D	SUSTAINER YAW	16-41	-4/4 Deg.
S257D	SUSTAINER PITCH	16-45	-4/4 Deg.
S258D	VERNIER 1 PITCH ROLL	16-3	-70/70 Deg.
S259D	VERNIER 2 PITCH ROLL	16-5	-70/70 Deg.
S260D	VERNIER 1 YAW	16-7	-5/55 Deg.
S261D	VERNIER 2 YAW	16-9	-55/5 Deg.
S52R	ROLL RATE GYRO SIGNAL	9	-8/8 Deg/sec
S53R	PITCH RATE GYRO SIGNAL	8	-6/6 Deg/sec
S54R	YAW RATE GYRO SIGNAL	5	-6/6 Deg/Sec
S190V	PITCH GYRO TORQUE AMPLIFIER	15-43	-1/1 VAC
S209V	PROGRAMMER 28 VDC TEST	6	20/35 VDC
S236X	BOOSTER CUTOFF DISCRETE	9-S	----
S241X	SUSTAINER CUTOFF DISCRETE	9-S	----
S245X	VERNIER CUTOFF DISCRETE	9-S	----
S248X	RELEASE PAYLOAD DISCRETE	9-S	----
S290X	PROGRAMMER OUTPUT/SPARE/BOOSTER JETTISON/ENABLE DISCRETES	16-29	0/28 VDC
S291X	PROGRAMMER OUTPUT/BECO/SECO/VECO	16-31	0/28 VDC
S359X	BOOSTER STAGING BACKUP	5-S	----
S384X	SPIN MOTOR TEST OUTPUT	15-5	0/5 VDC
U101A	AXIAL ACCELERATION	12	0/10 G
U80P	LOX TANK HEAD PRESS	16-11	0/5 VDC
U81P	FUEL TANK HEAD PRESS	16-13	0/2.5 PSID
U112V	ACOUSTICA COUNTER OUTPUT	15-23/53	0/5 VDC
U113V	ACOUSTICA VALVE POSITION FEEDBACK	13-33	0/5 VDC
U132V	ACOUSTICA STATION COUNTER OUTPUT	13-7	0/5 VDC
U134V	ACOUSTICA TIME SHARED OSCILLATOR OUTPUT	18-23/53	0/5 VDC
U135V	ACOUSTICA SENSOR SIGNAL	18-39	0/5 VDC
U605V	ACOUSTICA TIME SHARED INTEGRATOR SWITCH	18-35	0/5 VDC
Y44P	INTERSTAGE ADAPTER PRESS	13-23	0/15 PSIA
Y45T	INTERSTAGE ADAPTER TEMP	11-5	-200/200° F
Y41X	START D TIMER	5-S	----

(1) The first number indicates the IRIG subcarrier channel used. The second number indicates the commutated position for the measurement. If no second number is indicated, the channel was used continuously for the designated transducer.

(2) Items left blank are determined from a step increase in voltage.

APPENDIX C

ATS-1 TRACKING AND DATA ACQUISITION

APPENDIX C

ATS-1 TRACKING AND DATA ACQUISITION

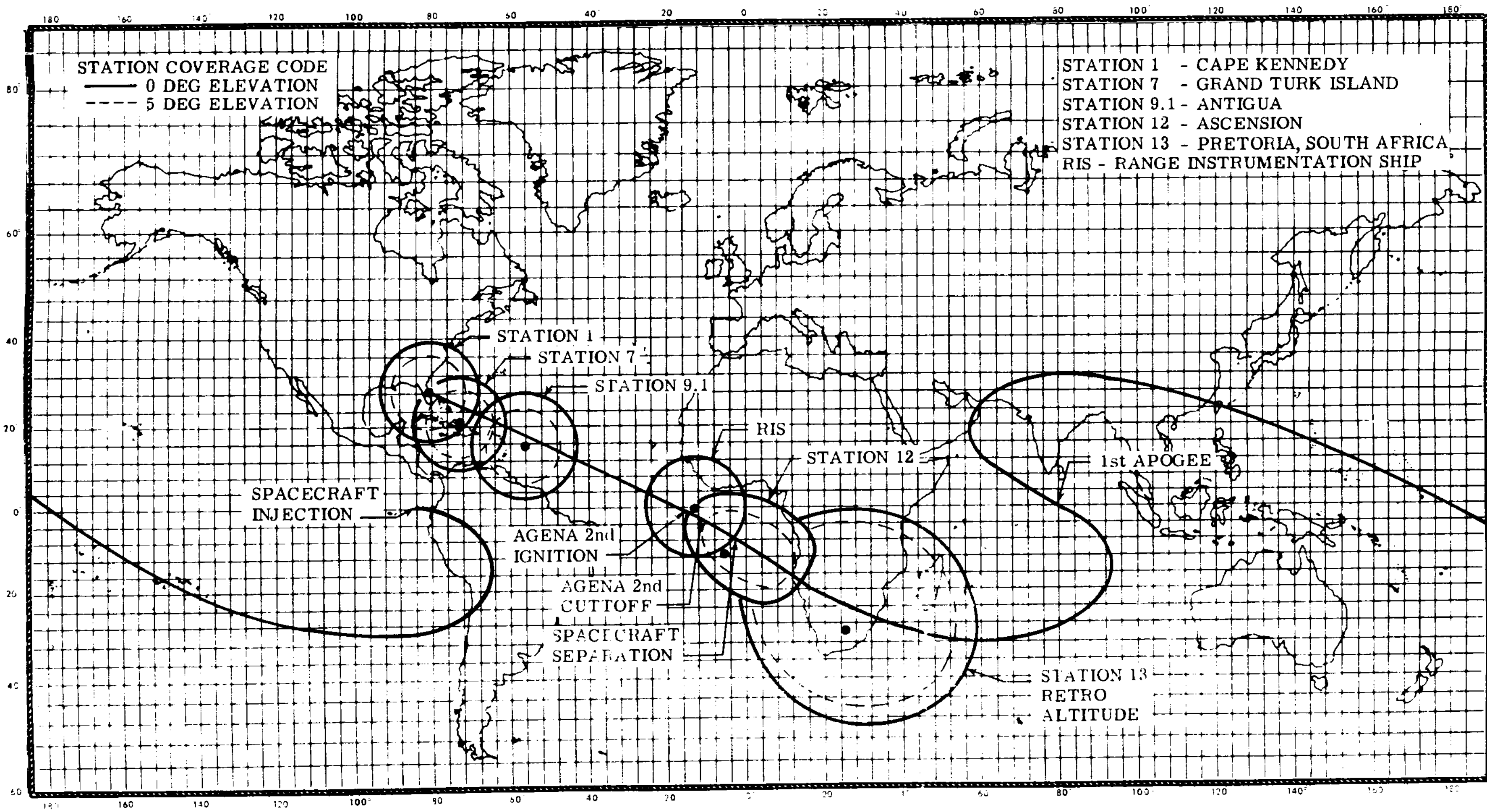
The launch vehicle trajectory, as projected on a world map, is shown in figure C-1. The Eastern Test Range uprange stations at Cape Kennedy, Grand Bahama Island, Grand Turk Island, and Antigua provided tracking and telemetry data. The downrange stations supporting this mission were Ascension, Pretoria, and the Range instrumentation ship "Twin Falls."

Telemetry Data

Telemetry signals from the Atlas/Agena launch vehicle were recorded on magnetic tape during all engine operations, Agena maneuvers, and spacecraft separation. Real-time monitoring of specific Atlas and Agena parameters was required for verification of significant flight events. The submarine cable linking the uprange stations permitted real-time monitoring at Cape Kennedy of vehicle telemetered signals through Agena first burn cutoff. The subsequent flight events were monitored by the downrange stations, and the time of occurrence reported back to Cape Kennedy in "near" real time by single side band radio link. The data recorded on magnetic tape was used for post flight analysis of the vehicle performance. Figure C-2 shows the specific telemetry coverage provided by the Eastern Test Range stations.

Radar Data

C-band radar metric data (time, elevation, azimuth, and range) were required for real-time operation and post flight analysis. Real-time radar data were used for monitoring the launch vehicle flight performance for safety purposes, and to assist the downrange stations in acquiring track of the vehicle. These data were also used for computation of parking orbit elements and injection conditions at Agena first burn cutoff, and for transfer orbital elements and injection conditions at Agena second burn cutoff. The radar coverage provided by the Eastern Test Range stations is presented in figure C-3.

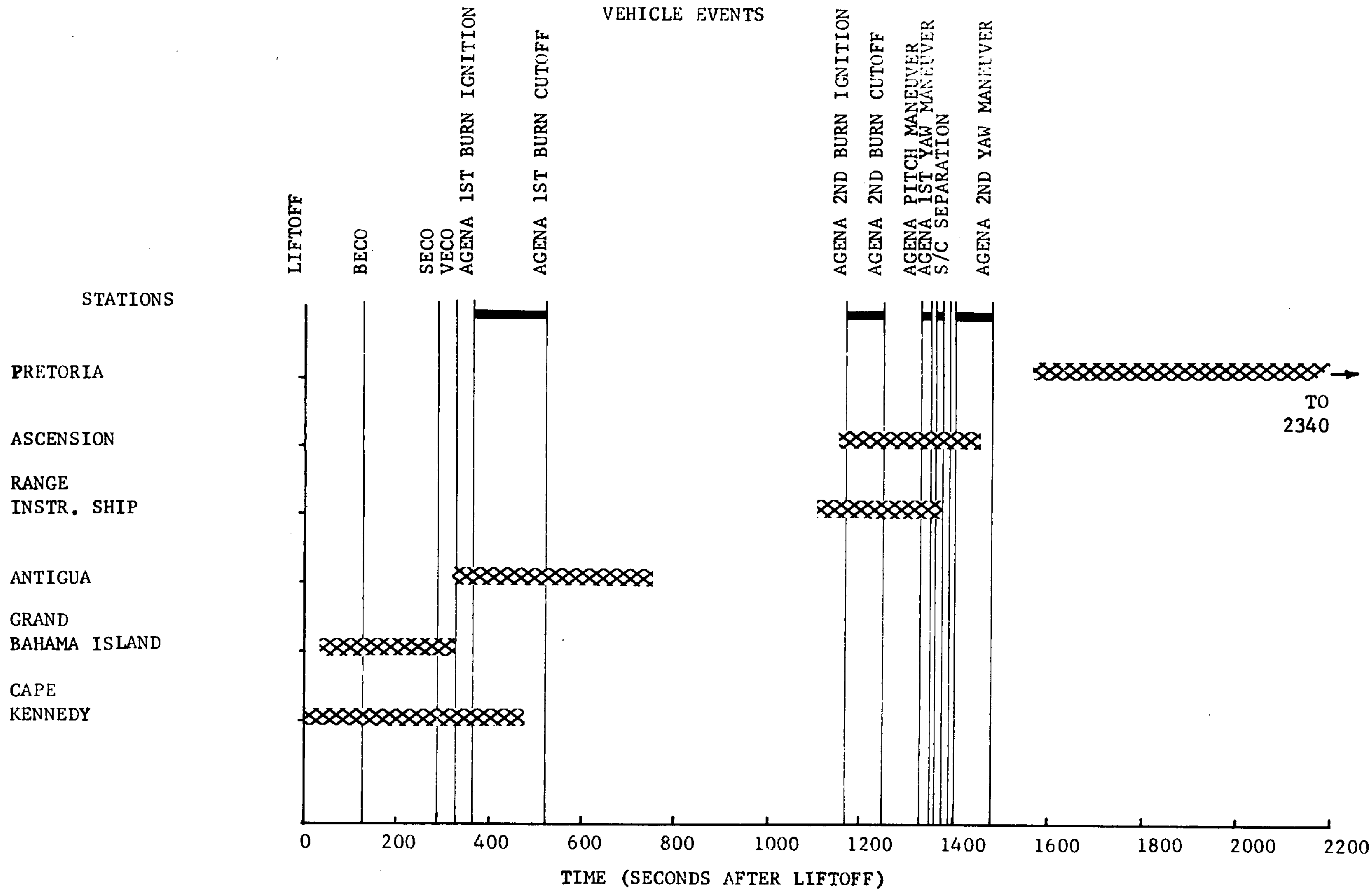


NORMAL GROUND TRACE FOR ATS-1

FIGURE C-1

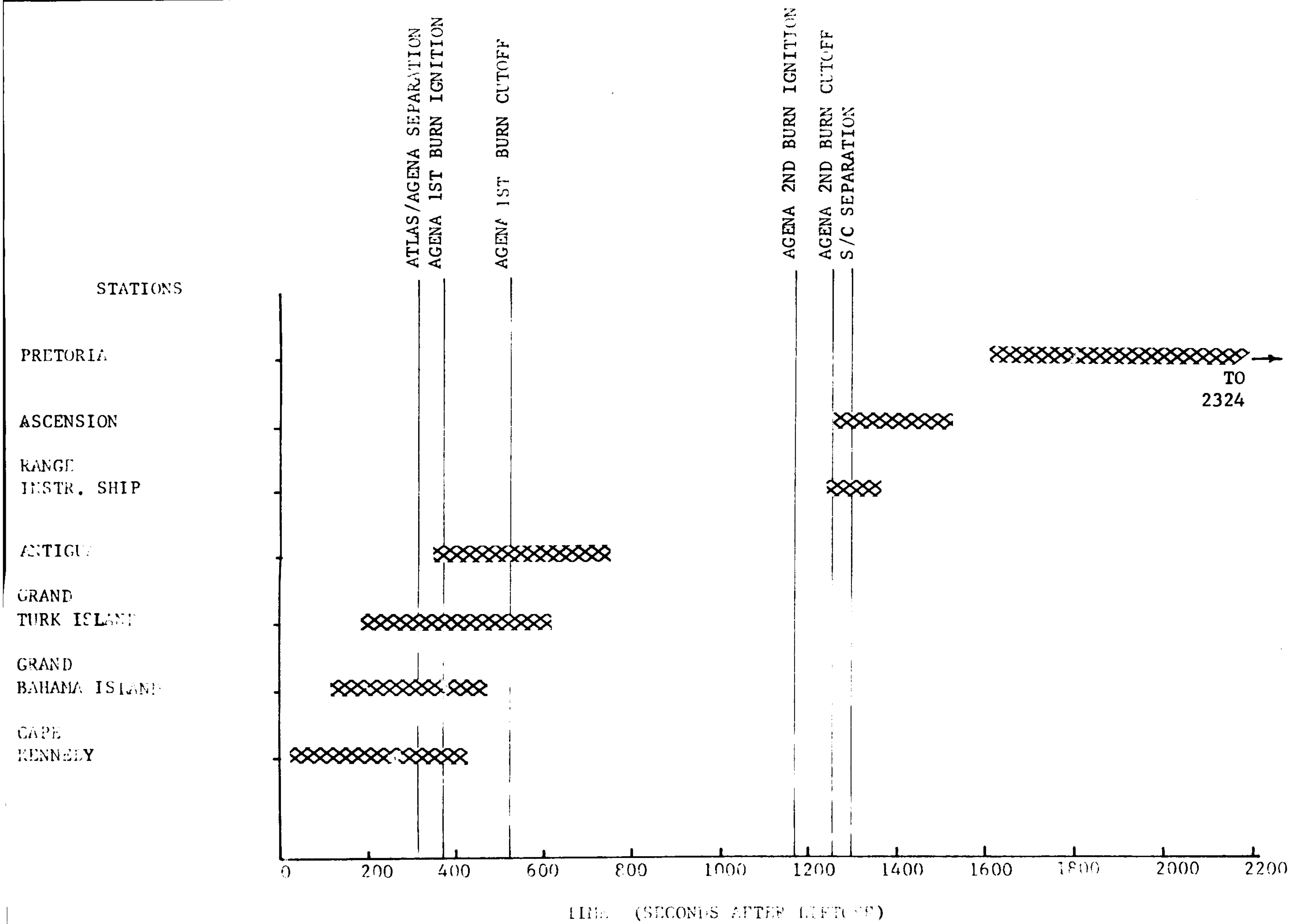
APPENDIX D

VEHICLE FLIGHT DYNAMICS



LAUNCH VEHICLE TELEMETRY COVERAGE

FIGURE C-2



LAUNCH VEHICLE RADAR COVERAGE

FIGURE C-3

APPENDIX D

VEHICLE FLIGHT DYNAMICS

Flight dynamic data for the ATS-1 Agena were obtained from three accelerometers installed in the Agena forward equipment section, and two vibration transducers on the spacecraft adapter. Instrumentation location and characteristics are shown in figure D-1. All instruments performed satisfactorily throughout the flight.

The flight data on Channels 17 and 18 indicate that the wire harnesses for Longitudinal Vibrometer A520 and Radial Vibrometer A524 were interchanged. Therefore, the flight dynamic data for the Longitudinal Vibrometer A520 were transmitted over Channel 17 instead of Channel 18, and the Radial Vibrometer A524 data were transmitted over Channel 18 instead of Channel 17. The presentation of the flight data herein reflects the "as flown" configuration.

The following table presents the actual flight times of events during which significant dynamic disturbances were recorded:

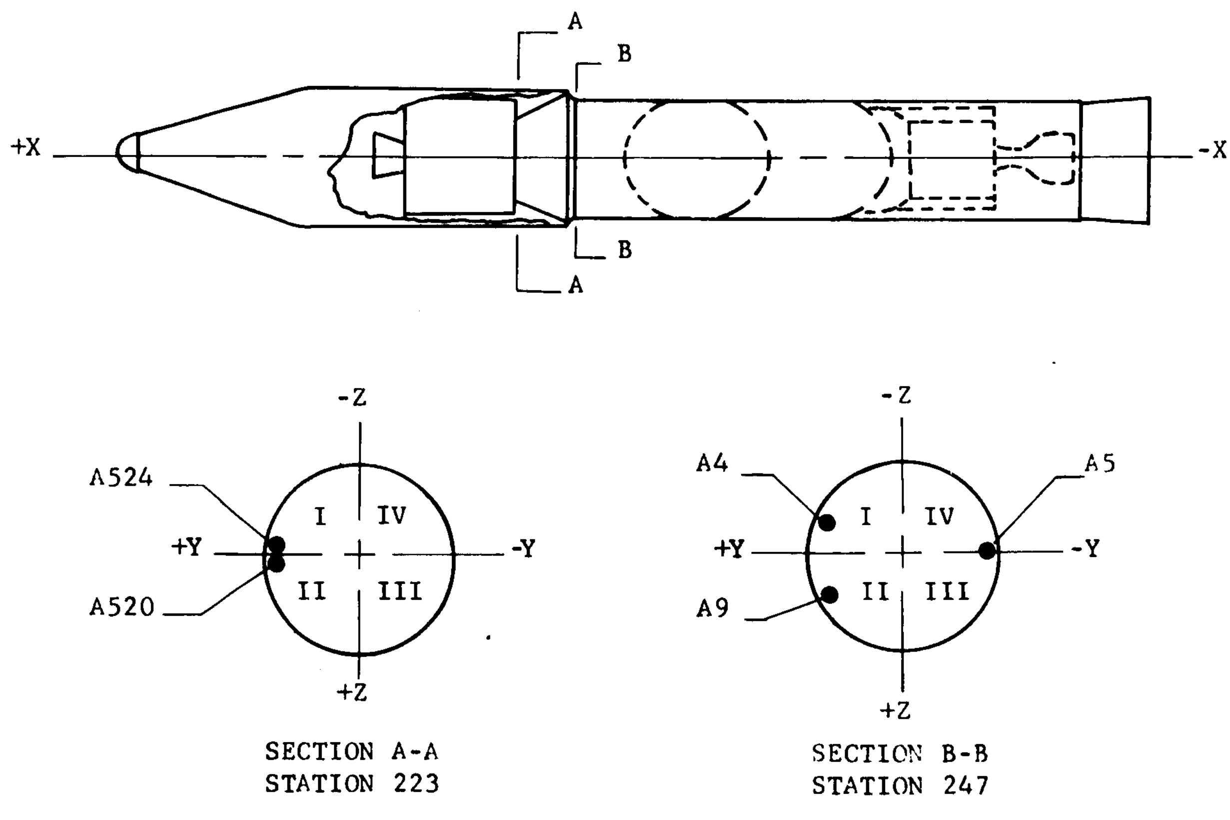
Event	Time After Liftoff (seconds)
Liftoff	0
Transonic	39-59
Booster Engine Cutoff (BECO)	129.1
Sustainer Engine Cutoff (SECO)	293.0
Jettison Horizon Sensor Fairing	312.9
Atlas/Agena Separation	315.1
First Burn 90% Thrust Build-up	360.4
Nose Shroud Separation	369.3
Agena First Cutoff	521.7
Agena Second Burn 90% Thrust Build-up	1171.4
Agena Second Cutoff	1248.7

The dynamic environment recorded by all five instruments for each one of these events is shown in figures D-2 through D-12.

The measured flight environment did not show any unexpected excitation, and the experienced shock levels were within expected ranges. A summary of the measurements is presented in table XII. An event of interest is BECO.

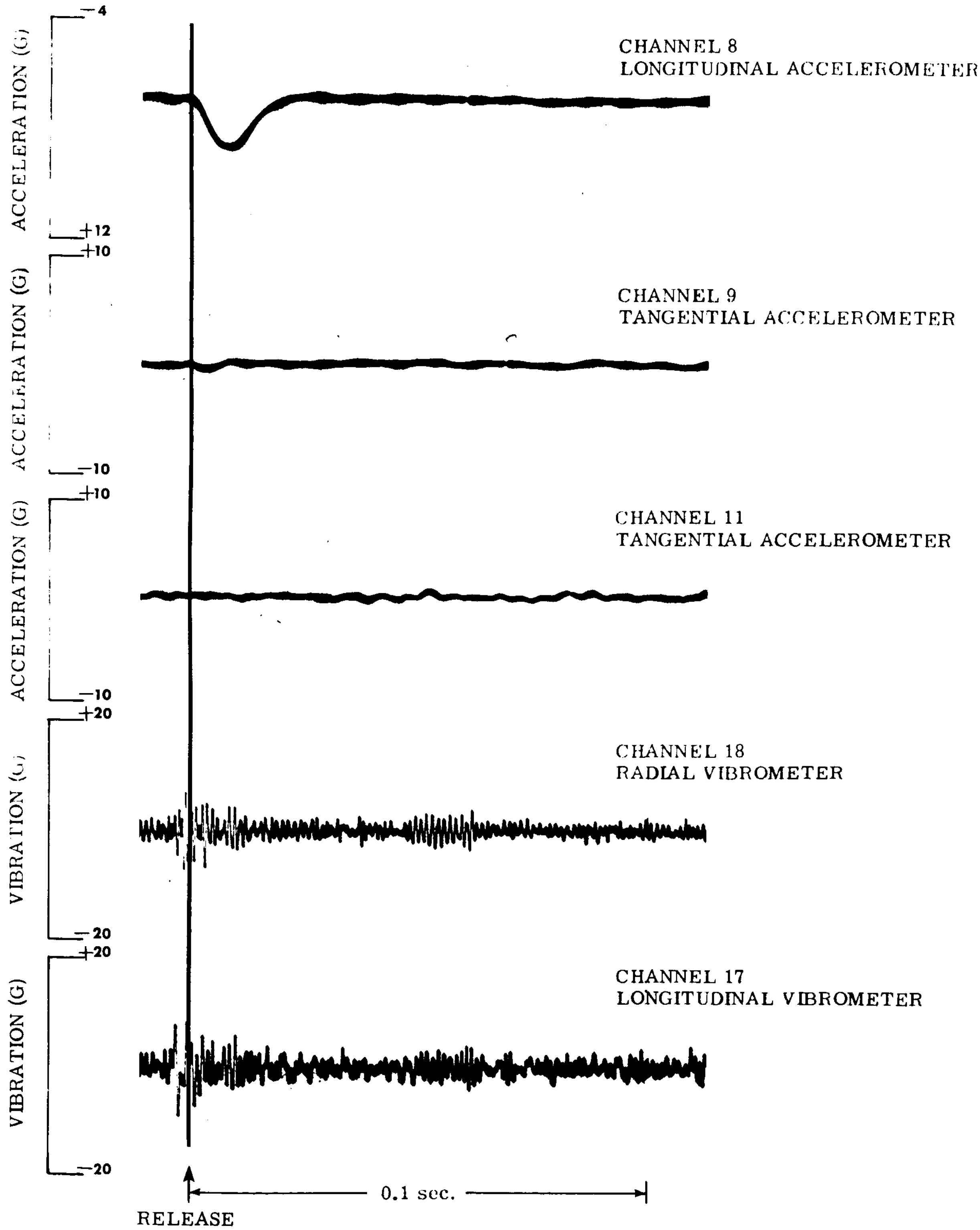
During BECO, transient oscillations of 0.5g (zero to peak) at 120-130 cps (see Channels 9 and 11 in fig. D-4) were observed on the tangential accelerometers. Since these accelerometers were not phase calibrated, no definite conclusions can be drawn concerning torsional motion during this transient. Data from previous flights indicate that this oscillation is torsional in nature. A longitudinal oscillation of 0.5g at 12 cps was also recorded during BECO. This indicates that the vehicle's first longitudinal mode was excited.

Channel	Measurement Description	Measurement No.	Frequency Response	Range	Transducer Orientation
8	Longitudinal Acceleration	A9 @ St. 247	0-35 cps.	-4 to +12g	X Dir., II Quad
9	Tangential Acceleration	A4 @ St. 247	0-110 cps	±10 g	Z Dir., I Quad
11	Tangential Acceleration	A5 @ St. 247	0-160 cps	±10 g	Z Dir., III Quad
17	Axial Vibration	A520 @ St. 223	To 20 cps 2 KC	±20 g	± X, + Y Axis
18	Radial Vibration	A524 @ St. 223	To 20 cps 1.5 KC	±20 g	± Y, + Y Axis



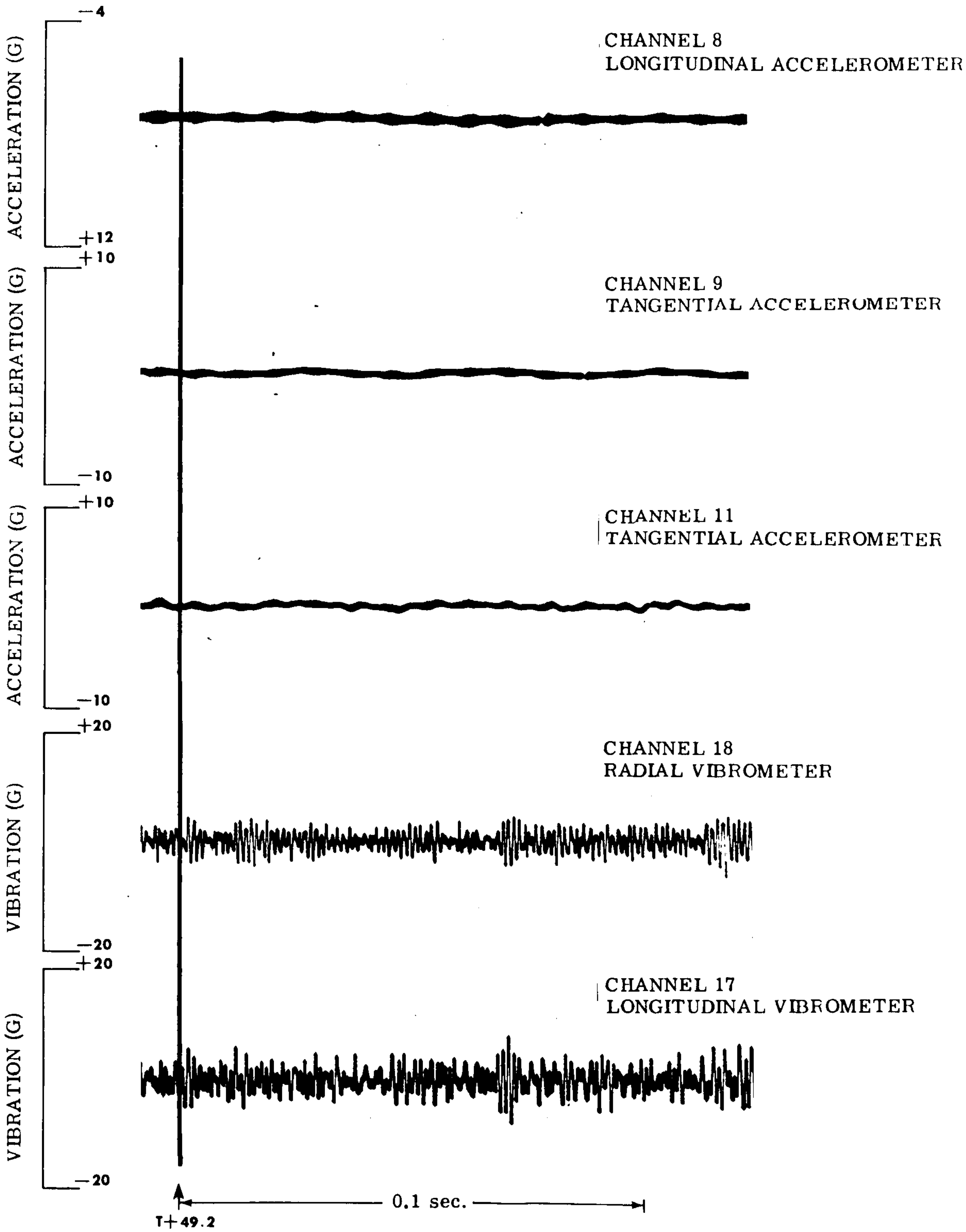
FLIGHT INSTRUMENTATION

FIGURE D-1

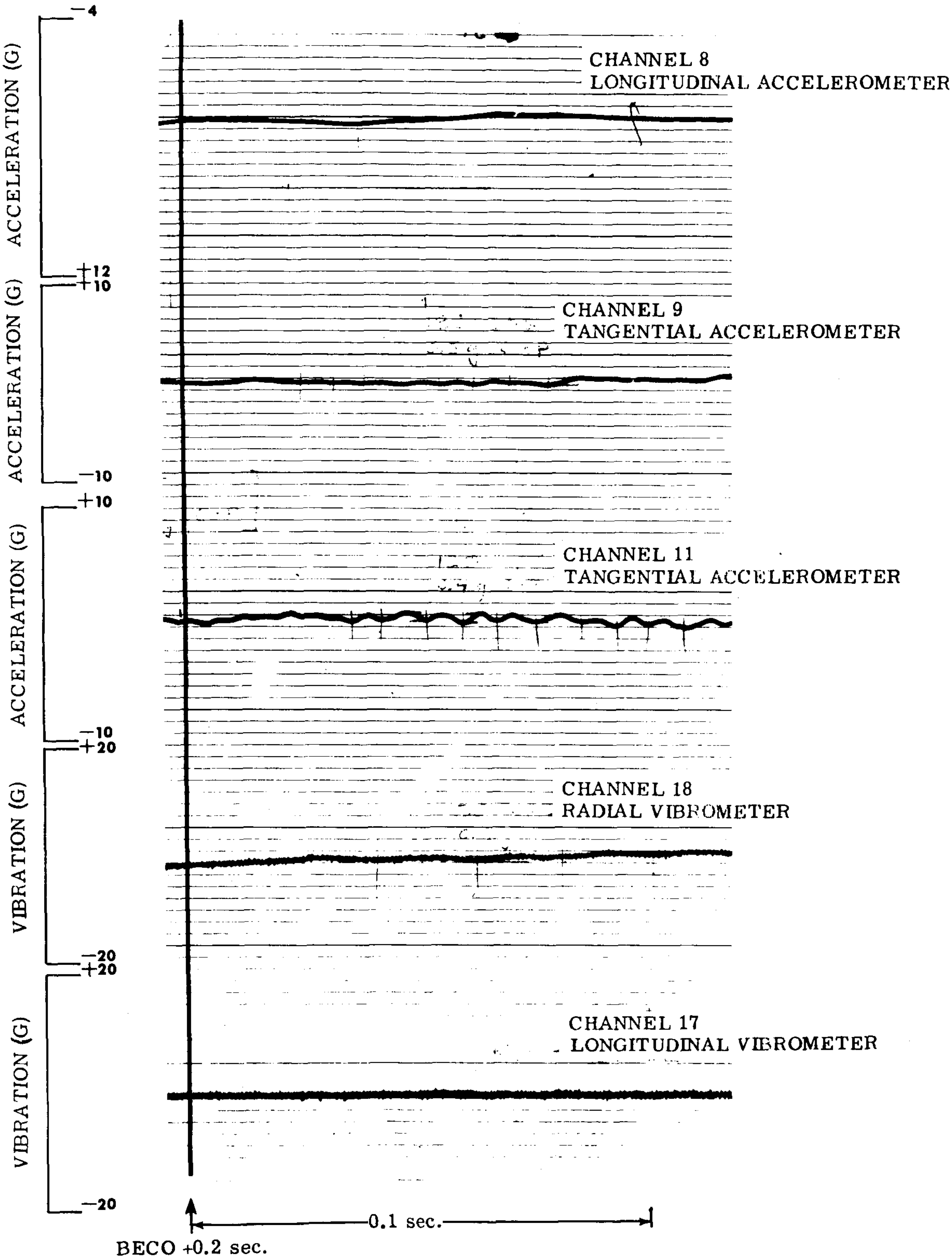


LIFTOFF

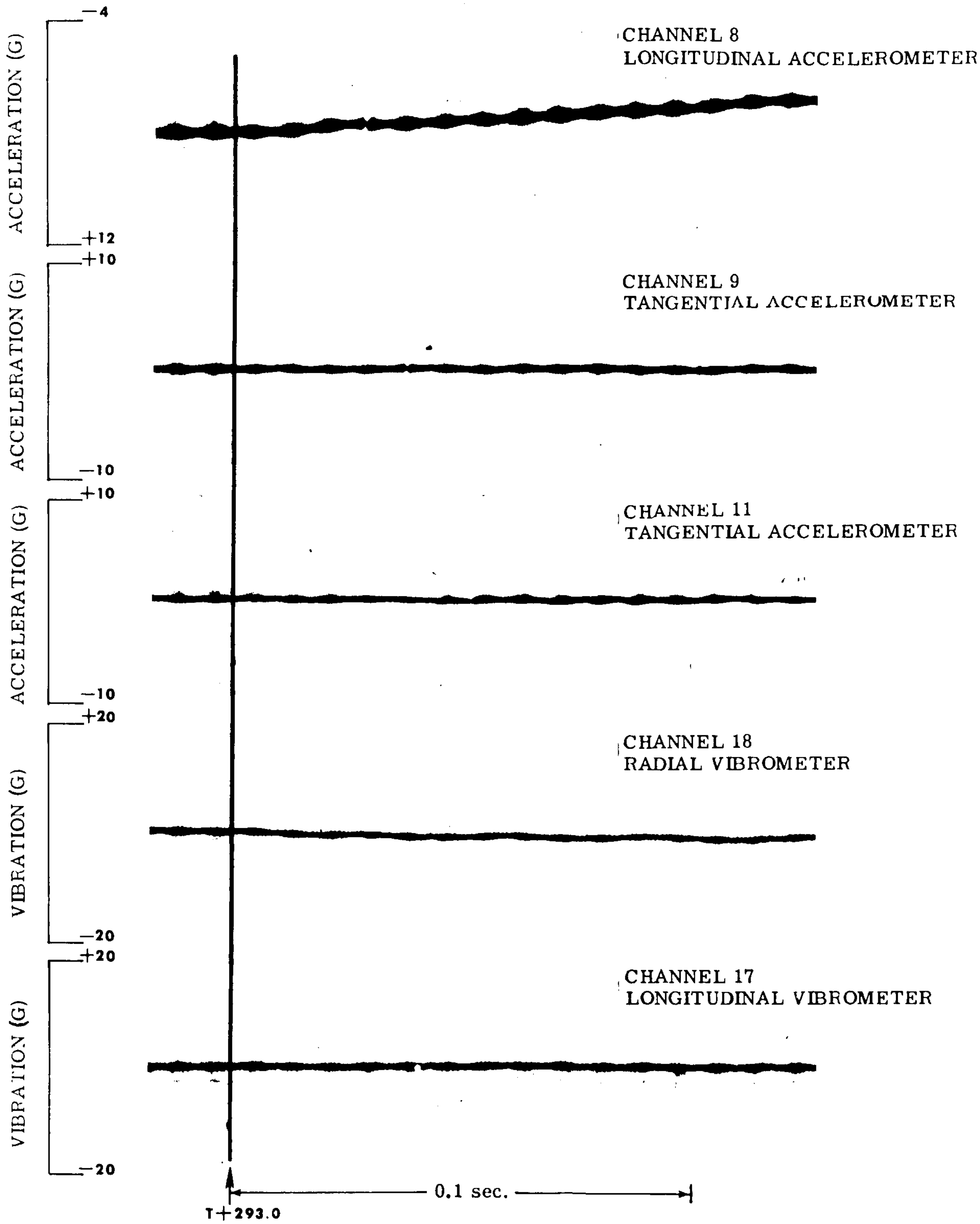
FIGURE D-2



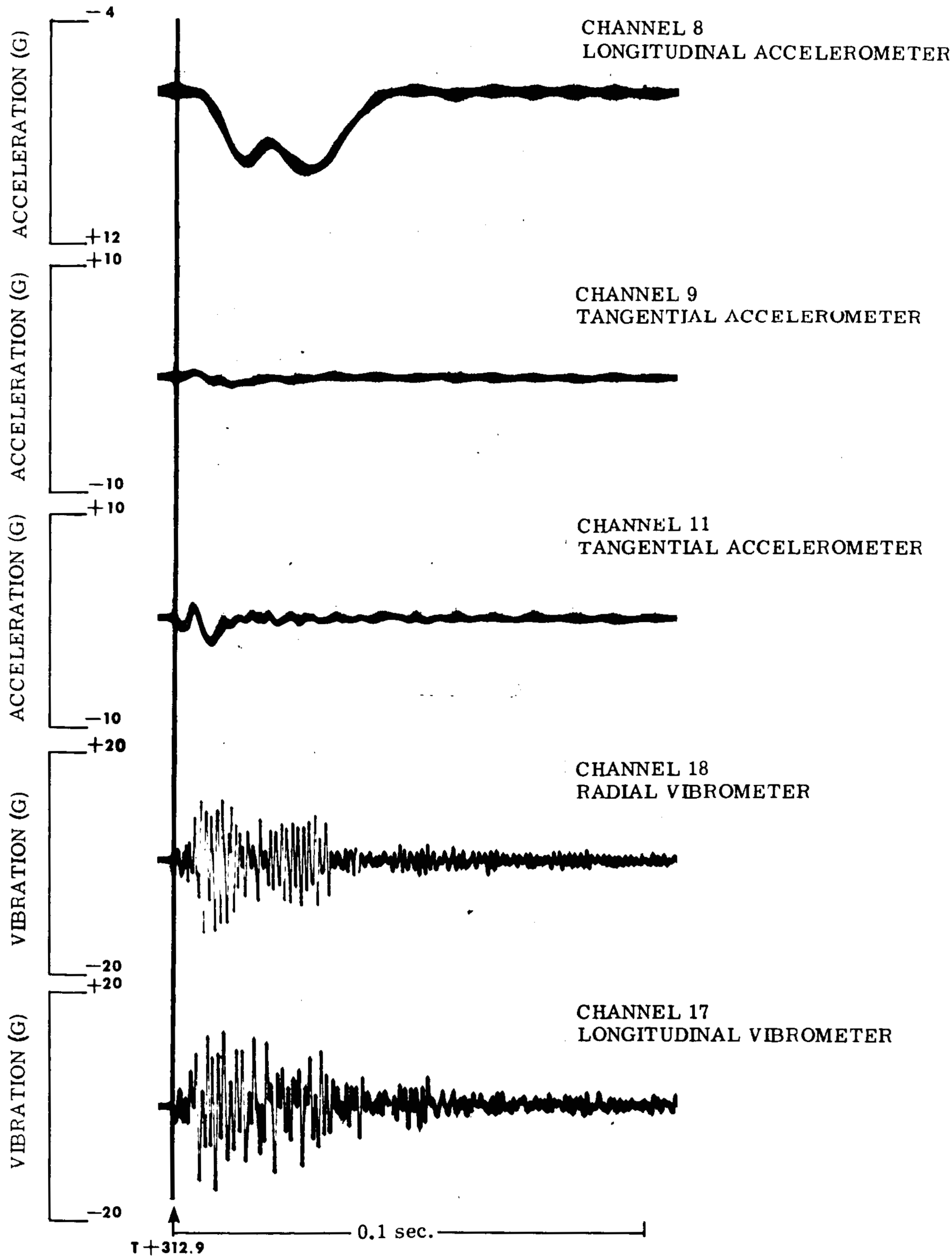
TRANSONIC
FIGURE D-3



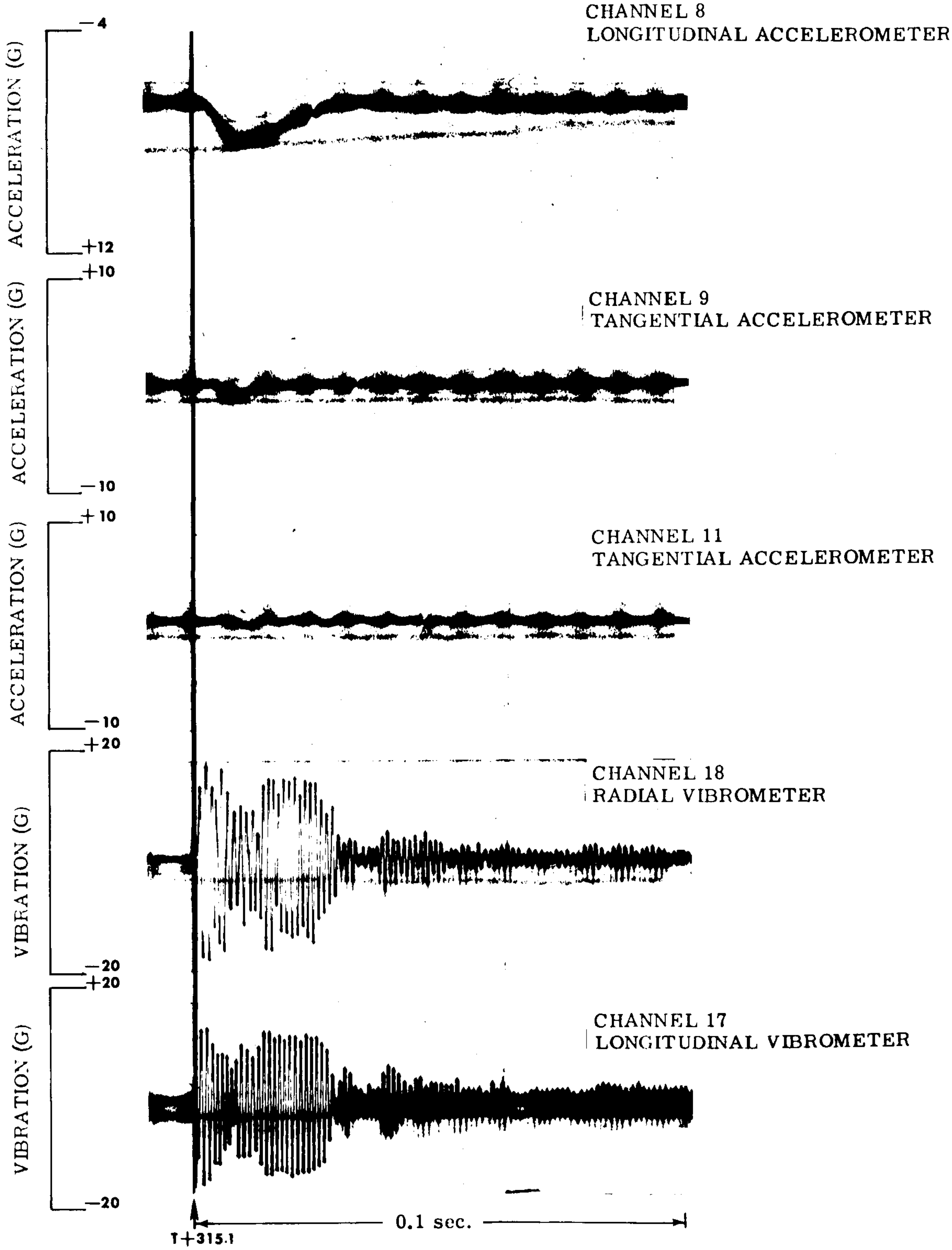
BOOSTER ENGINE CUTOFF
FIGURE D-4



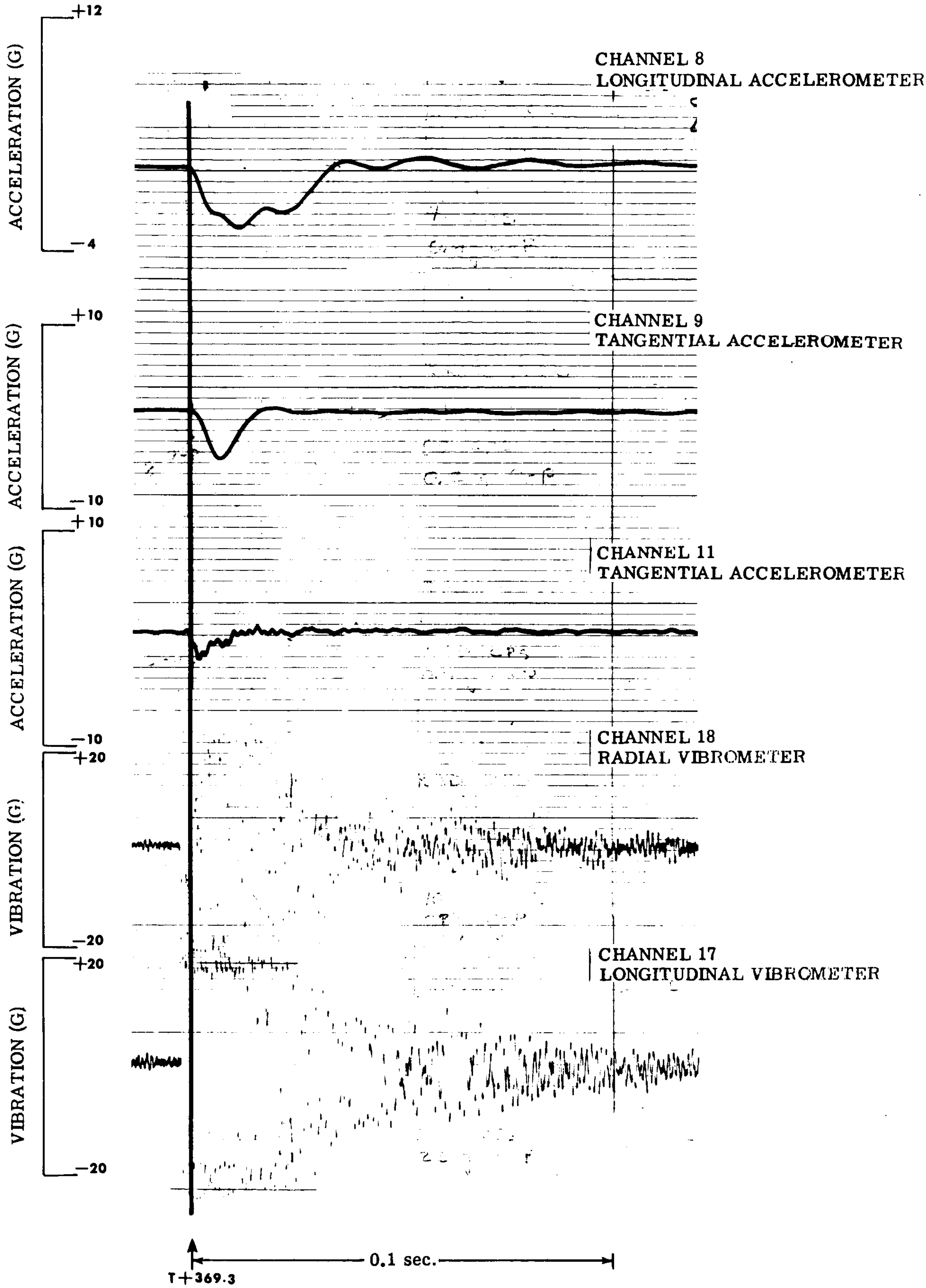
SUSTAINER ENGINE CUTOFF
FIGURE D-5



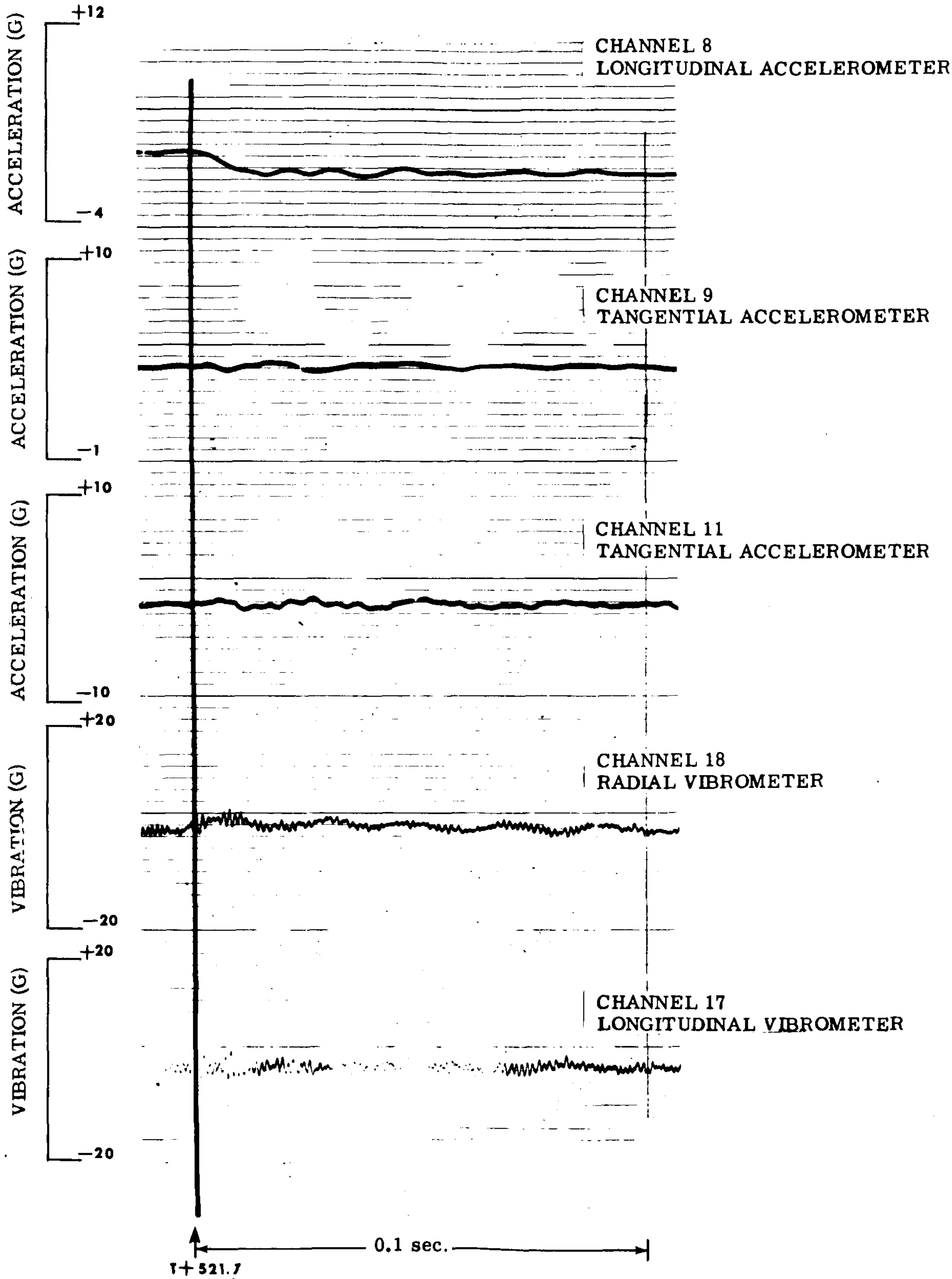
HORIZON SENSOR FAIRING JETTISON
FIGURE D-6



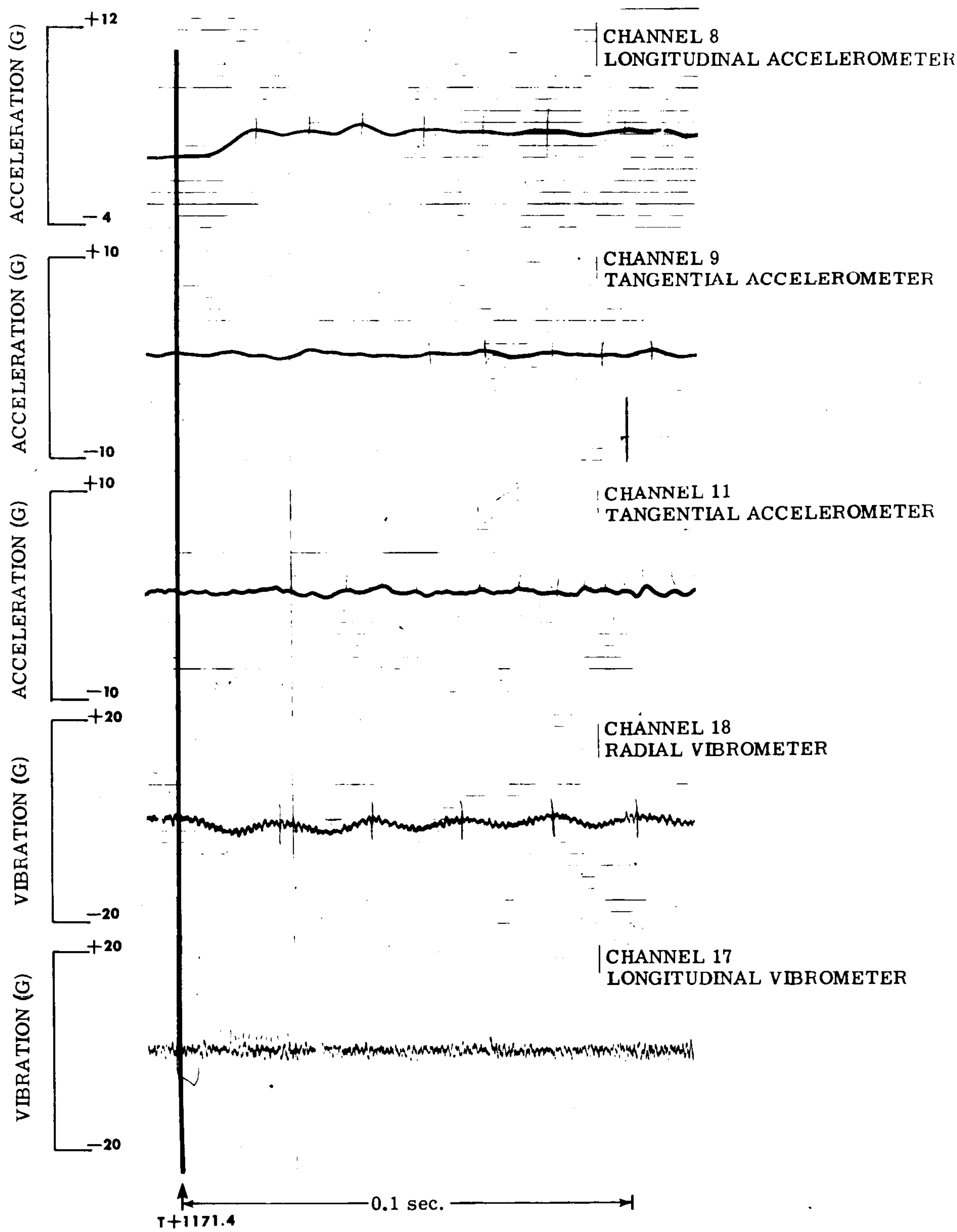
ATLAS/AGENA SEPARATION
FIGURE D-7



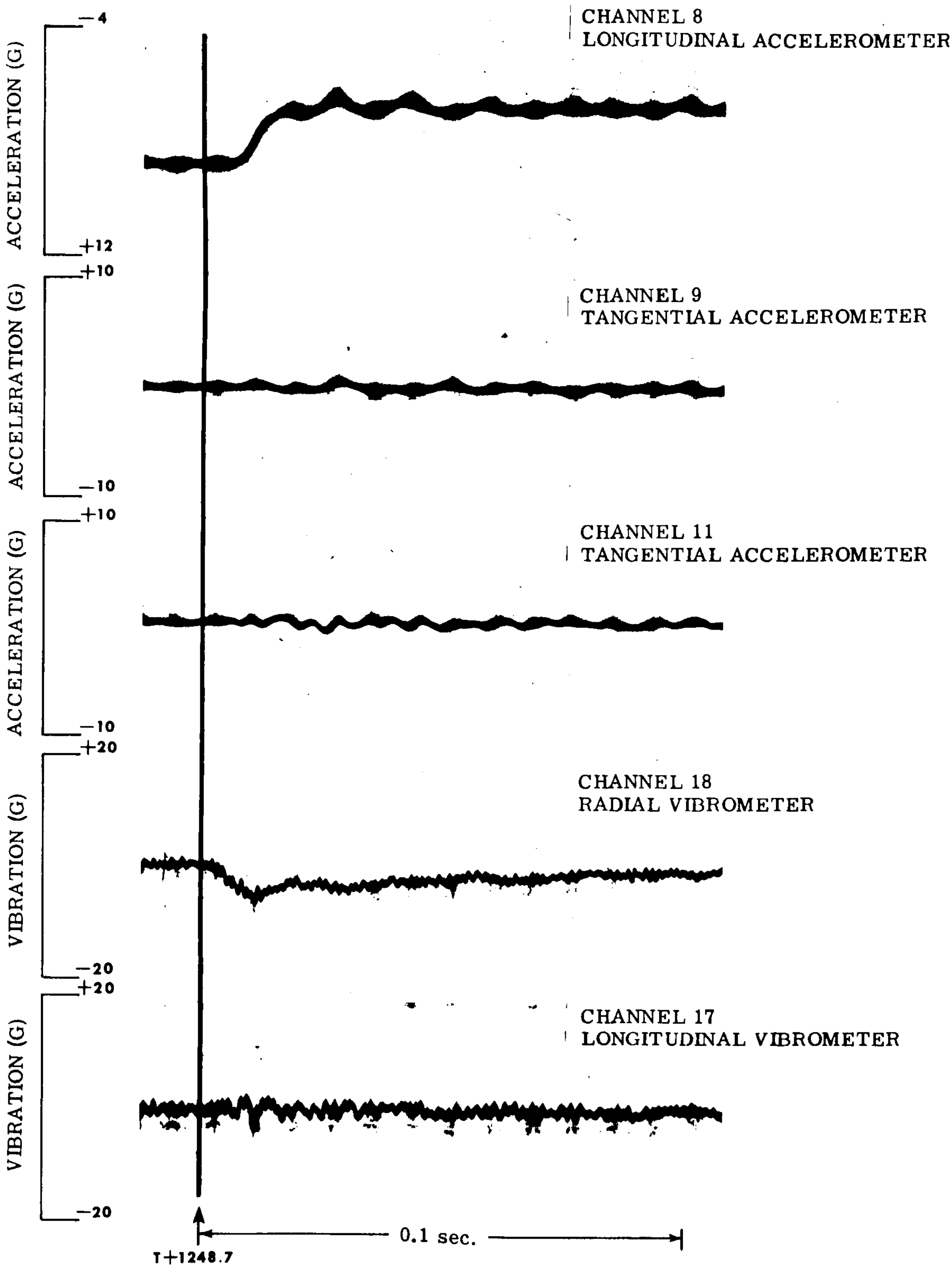
SHROUD SEPARATION
FIGURE D-8



AGENA FIRST BURN CUTOFF
FIGURE D-9



AGENA SECOND BURN IGNITION
FIGURE D-10



AGENA SECOND BURN CUTOFF
FIGURE D-11

APPENDIX E

AGENA

TELEMETRY INSTRUMENTATION SCHEDULE

APPENDIX E

AGENA
TELEMETRY INSTRUMENTATION SCHEDULE

Meas. No.	Description	Channel Assignment (1)	Measurement Range Low/High (4)
A4	Tangential Accelerometer	9	-10/10 G
A5	Tangential Accelerometer	11	-10/10 G
A9	Longitudinal Accelerometer	8	-4/12 G
A52	Shroud Separation	15-44	
A226	Shroud Inside Temperature	16-31	32/500° F
A227	Shroud Inside Temperature	16-33	32/500° F
A519	Shroud Cavity Pressure	16-12/23/34	-5/5 PSID
A520	S/C Adapter Longitudinal Vibration	17(2)	-20/20 G
A524	S/C Adapter Radial Vibration	18(2)	-20/20 G
B1	Fuel Pump Inlet Pressure	15-17	0/100 PSIG
B2	Oxidizer Pump Inlet Pressure	15-17	0/100 PSIG
B11	Oxidizer Venturi Inlet Pressure	15-19/49	0/1500 PSIA
B12	Fuel Venturi Inlet Pressure	15-23/53	0/1500 PSIA
B13	Switch Group Z	15-7/22/37/52	
B31	Fuel Pump Inlet Temperature	15-6	0/100° F
B32	Oxidizer Pump Inlet Temperature	15-8	0/100° F
B35	Turbine Speed(3)		(3)
B91	Combustion Chamber Pressure No. 3	15-4/34	475/550 PSIG
C1	28 VDC Unregulated Supply	16-40	22/30 VDC
C3	+28 VDC Regulator (C&C)	15-12	22/30 VDC
C4	28 VDC Unregulated Current	16-13/44	0/100 AMP
C5	-28 VDC Regulator (G&C)	15-30	-30/-22 VDC
C21	400 cps, 3Q; Inverter Temperature	15-14	0/200° F
C31	400 cps, 3Q; BusPh. AB	15-18	90/128 VAC
C32	400 cps, 3Q; BusPh. BC	15-20	90/128 VAC
C38	Structure Current Monitor	15-10/25/40/55	0/50 AMP
C141	Pyro Bus Voltage	15-5/35	22/30 VDC
D14	Guidance and Control Monitor	16-27	
D41	Horizon Sensor Pitch	16-45	-5/5 DEG
D42	Horizon Sensor Roll	16-46	-5/5 DEG
D46	Gas Valve Cluster Temperature 1	15-39	-50/150° F
D47	Gas Valve Cluster Temperature 1	15-36	-50/150° F
D51	Yaw Torque Rate (Ascent Mode)	16-38	-200/200 D/MIN
D51	Yaw Torque Rate (Orbital Mode)	16-38	-10/10 D/MIN
D54	Horizon Sensor Head Temperature (RH)	15-47	-50/200° F

Meas. No.	Description	Channel Assignment (1)	Measurement Range Low/High (4)
D55	Horizon Sensor Head Temperature (LH)	15-46	-50/200° F
D59	Control Gas Supply Pressure (high)	16-47	0/4000 PSIA
D60	Hydraulic Oil Pressure	15-21	0/4000 PSIA
D66	Roll Torque Rate	16-41	-50/50 D/MIN -4/4 D/MIN
D68	Pitch Actuator Position	15-3	-2.5/2.5 DEG
D69	Yaw Actuator Position	15-24	-2.5/2.5 DEG
D70	Control Gas Supply Temperature	15-42	-50/200° F
D72	Pitch Gyro Output	16-36	-10/10 DEG -5/5 DEG
D73	Pitch Torque Rate (Ascent Mode)	16-35	-200/200 D/MIN
D73	Pitch Torque Rate (Orbital Mode)	16-35	-10/10 D/MIN
D74	Yaw Gyro Output	16-39	-10/10 DEG -5/5 DEG
D75	Roll Gyro Output	16-42	-10/10 DEG -5/5 DEG
D83	Velocity Meter Acceleration	14	Binary Code
D86	Velocity Meter Cutoff Switch	16-28	
D88	Velocity Meter Counter	14	Binary Code
D129	IRP Internal Case Temperature	15-54	0/155° F
D149	Gas Valves 1 through 6 Current	7	(5)
H47	Beacon Receiver PRF	15-27	0/1600 PPS
H48	Beacon Transmitter PRF	15-28	0/1600 PPS
H101	Safe-Arm-Fire Destruct No. 1	16-2	
H103	Safe-Arm-Fire Destruct No. 2	16-4	
H204	DC/DC Converter No. 1	15-50	22/30 VDC
H218	Telemetry Transmitter Temperature	16-49	50/170° F
H354	Destruct Receiver No. 1 Signal Level	16-6	0/40 UV
H364	Destruct Receiver No. 2 Signal Level	16-8	0/40 UV

N.B.

(1) The first number indicates the IRIG subcarrier channel used. The second number indicates the commutated position for the measurement. If no second number is indicated, the channel was used continuously for the designated transducer.

(2) Preflight plan had intended channels 17 and 18 to be switched from those shown here; however, flight data indicates that A524 was transmitted over Channel 18 and A520 was transmitted over Channel 17.

(3) The turbine speed signal does not utilize a subcarrier channel, but directly modulates the transmitter during engine operation.

(4) Items left blank are determined from a step change in voltage.

(5) A unique voltage level is associated with any one or combination of gas jet activity.

APPENDIX F

ABBREVIATIONS

APPENDIX F

ABBREVIATIONS

ac	alternating current
Acc	accelerometer
B-Fact	booster flight acceptance composite test
Cape	Cape Kennedy
cu ft	cubic foot (feet)
db	decibel
dbm	decibels referenced to a one milliwatt power load
dc	direct current
deg	degree
deg/min	degree per minute
deg/sec	degree per second
EST	Eastern Standard Time
^{o}F	degrees Fahrenheit
FM	frequency modulation
fps	feet per second
ft	foot (feet)
g	acceleration equal to 32 feet per second per second
G&C	guidance and control
H/S	horizon sensor
Hz	Hertz (cycle per second)
in.	inch (inches)
IRIG	Interrange Instrumentation Group
J-Fact	joint flight acceptance composite test
kc	kilocycles
lb	pound
LeRC	Lewis Research Center
LOX	liquid oxygen
max.	maximum
mHz	mega hertz
MILA	Merrit Island Launch Area
min	minute (minutes)
min.	minimum
Ox	oxygen
O-P	zero to peak
PAM	pulse amplitude modification

PIV	propellant isolation valve
PPS	pulses per second
P&R	pitch and roll
P&Y	pitch and yaw
psi	pounds per square inch
psia	pounds per square inch absolute
psid	pounds per square inch differential
psig	pounds per square inch gauge
QUAD	quadrant
RF	radio frequency
rms	root mean square
rpm	revolutions per minute
rps	revolutions per second
sec	second (seconds)
SEP	Atlas/Agena separation
STA.	station
stg	staging
T	time of lift-off (2 inch motion)
T&C	tracking and communication
USAF	United States Air Force
uV	microvolts
V	volts
Vac	voltage alternating current
Vdc	voltage direct current
VHF	very high frequency
V/M	velocity meter

E-4161

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